Rotating Equipment Alignment

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Rotating Equipment Alignment (One of the most cause of failure)

- Types of Couplings
- Alignment Preparation check list
- Preparation on Alignment
- How to Do Alignment
- Isolation Standard
- ***(Software for Pumps Alignment Calculations)***

- Post assessment

Rotating Equipment Alignment (One of the most cause of failure)

It is collinear of two center lines

1-Is the proper positioning of the shaft centerlines of the driver and driven components.

2-Alignment is accomplished either

A- Shimming

B- Moving a machine component.

Its objective is to obtain a common axis of rotation at operating equilibrium for two coupled shafts or a train of coupled shafts.

Why it is important to make shaft alignment?

Shafts must be aligned as perfectly as possible to maximize equipment reliability and life, particularly for high-speed

It is important because misalignment can introduce

1-High level of vibration
2-Cause bearings to run hot

Proper alignment

1-Reduces power consumption and noise level
2-Helps to achieve the design life of bearings, seals, and couplings.

Types Of Couplings

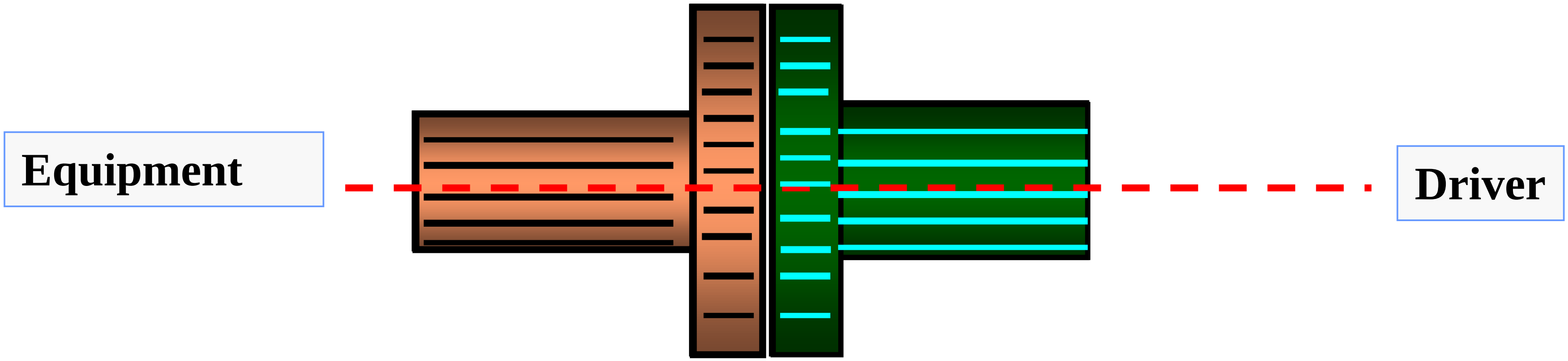
1 -Rigid Couplings :

It is a metal to metal contact (%100 collinear)

2 -Flexible Couplings

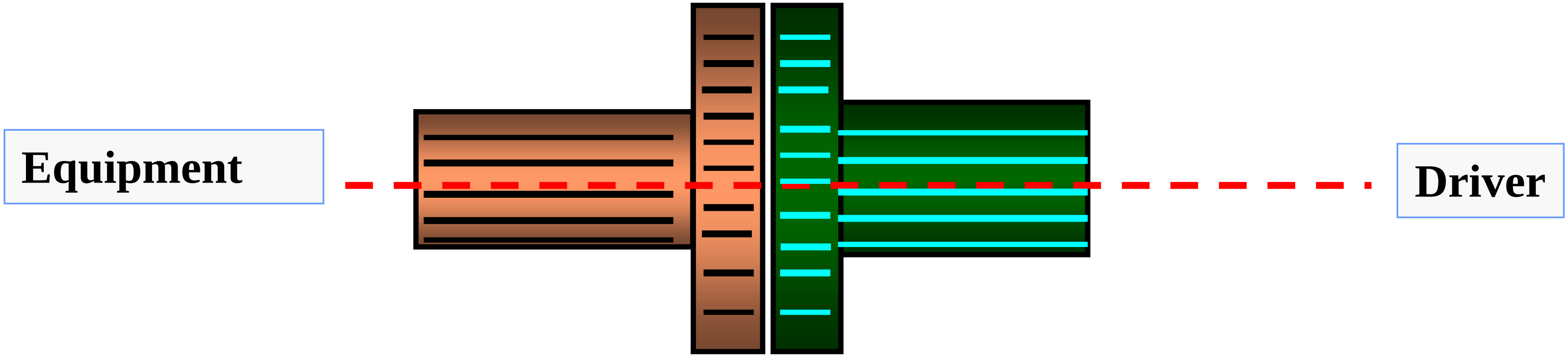
** Spacer with shims*
** Gear*
** Grid*
** Rubber*
** Others*
** Torque converter*

Alignment



Misalignment

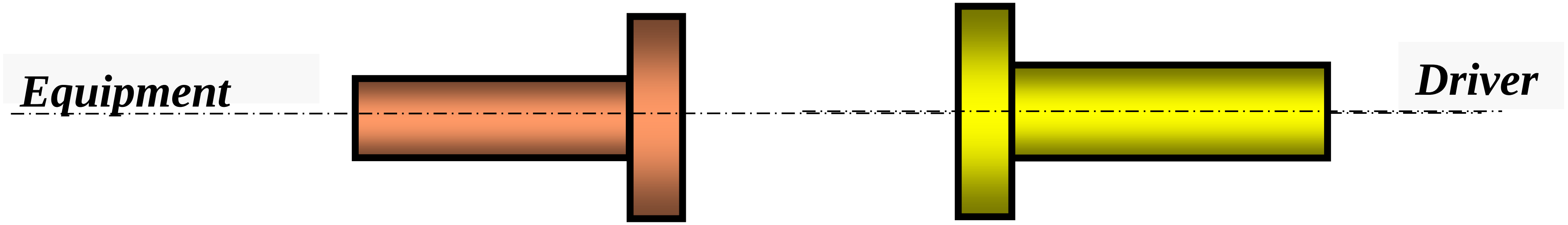
It is important because misalignment can introduce a high level of vibration, cause bearings to run hot, and result in frequent repairs of bearings, seals, and couplings.
Proper alignment reduces power consumption and noise level, and helps to achieve the design life of bearings, seals, and couplings.

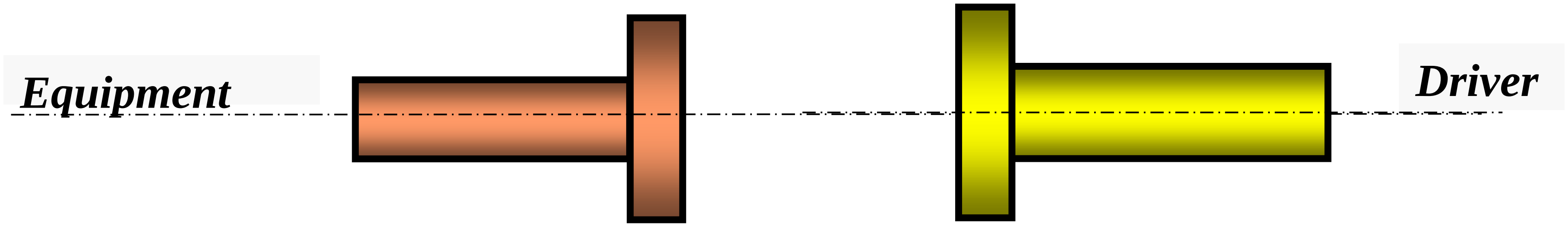


Alignment

Types Of Misalignment

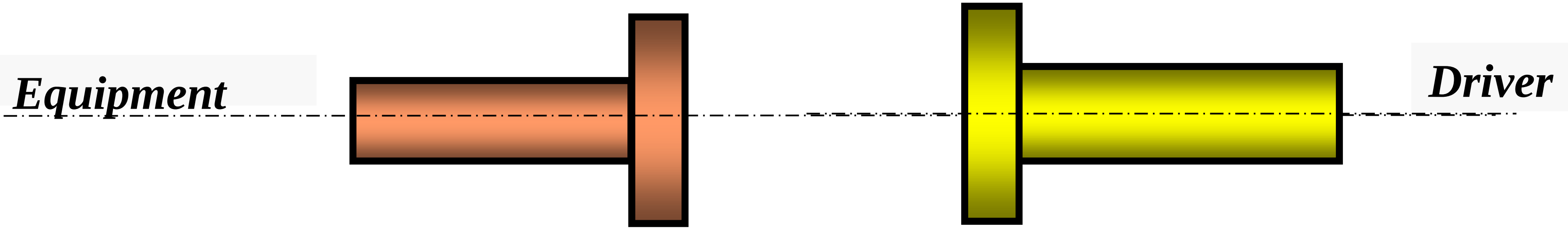
Vertical View

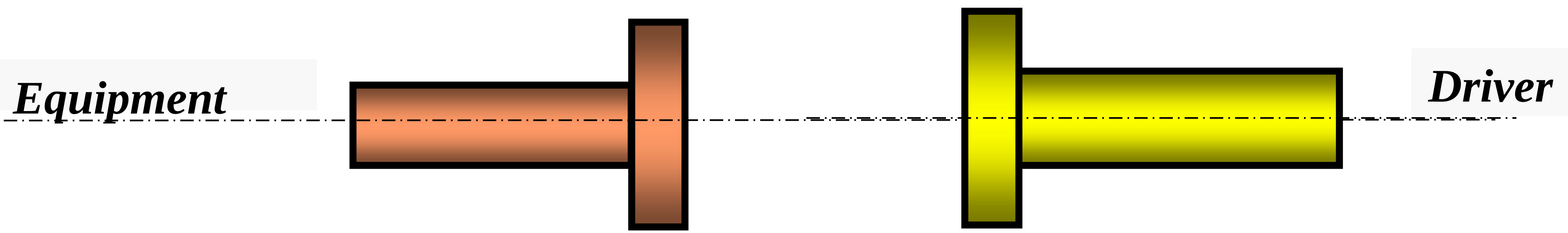




Types Of Misalignment

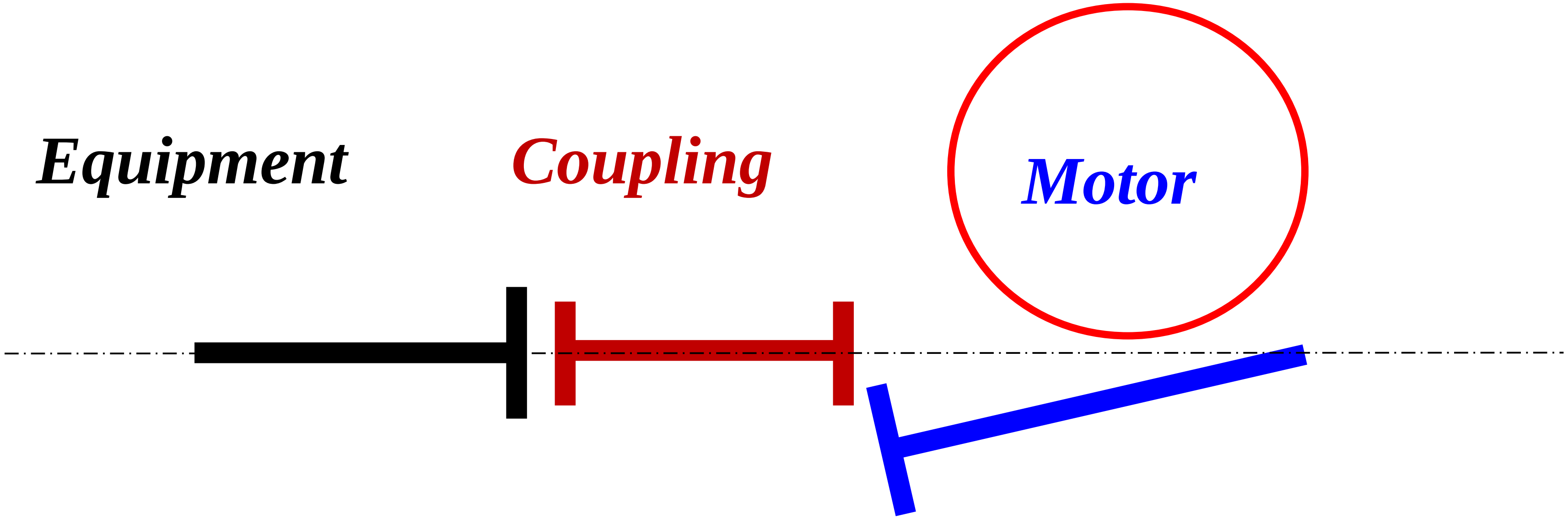
Horizontal View



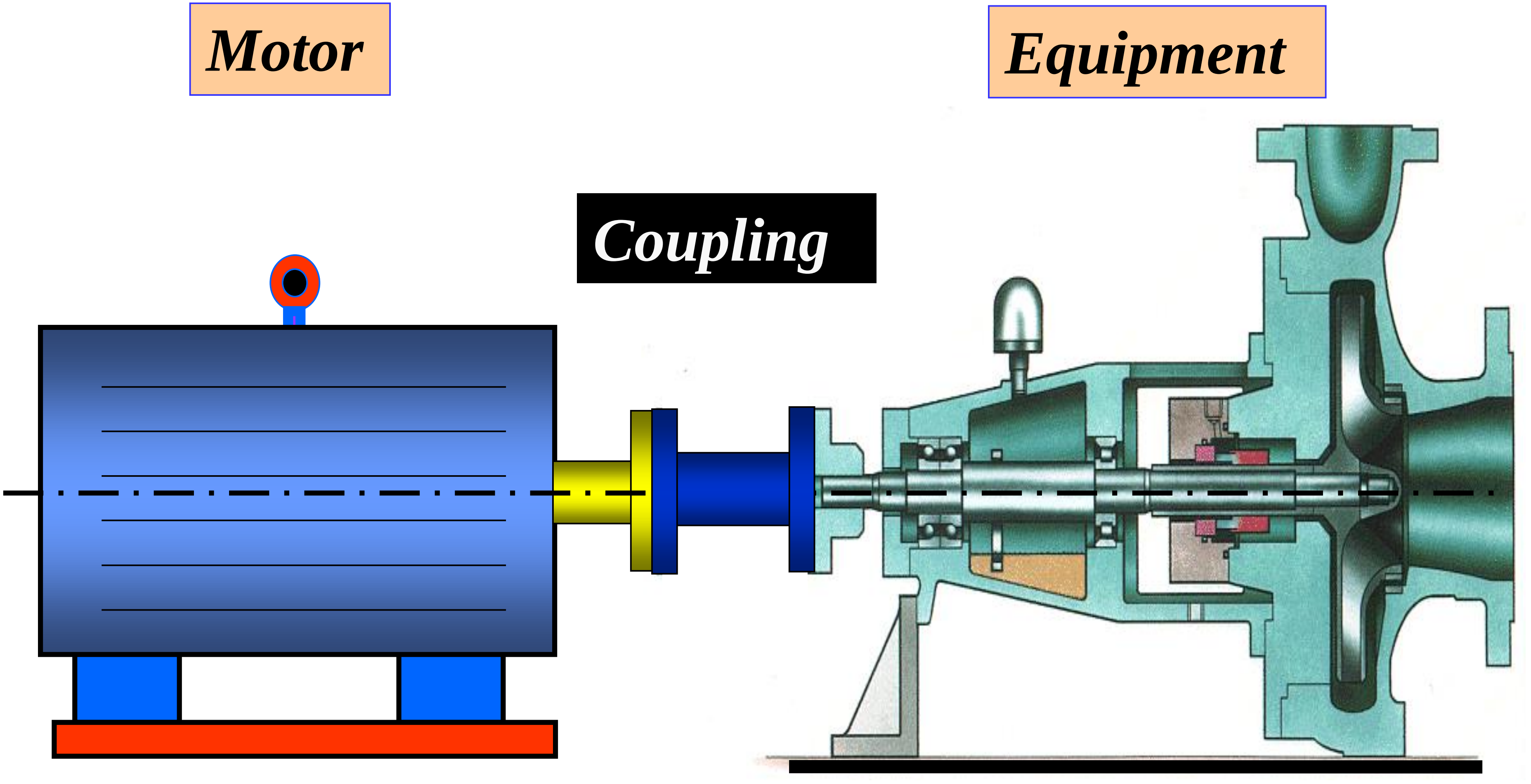


Alignment Procedures

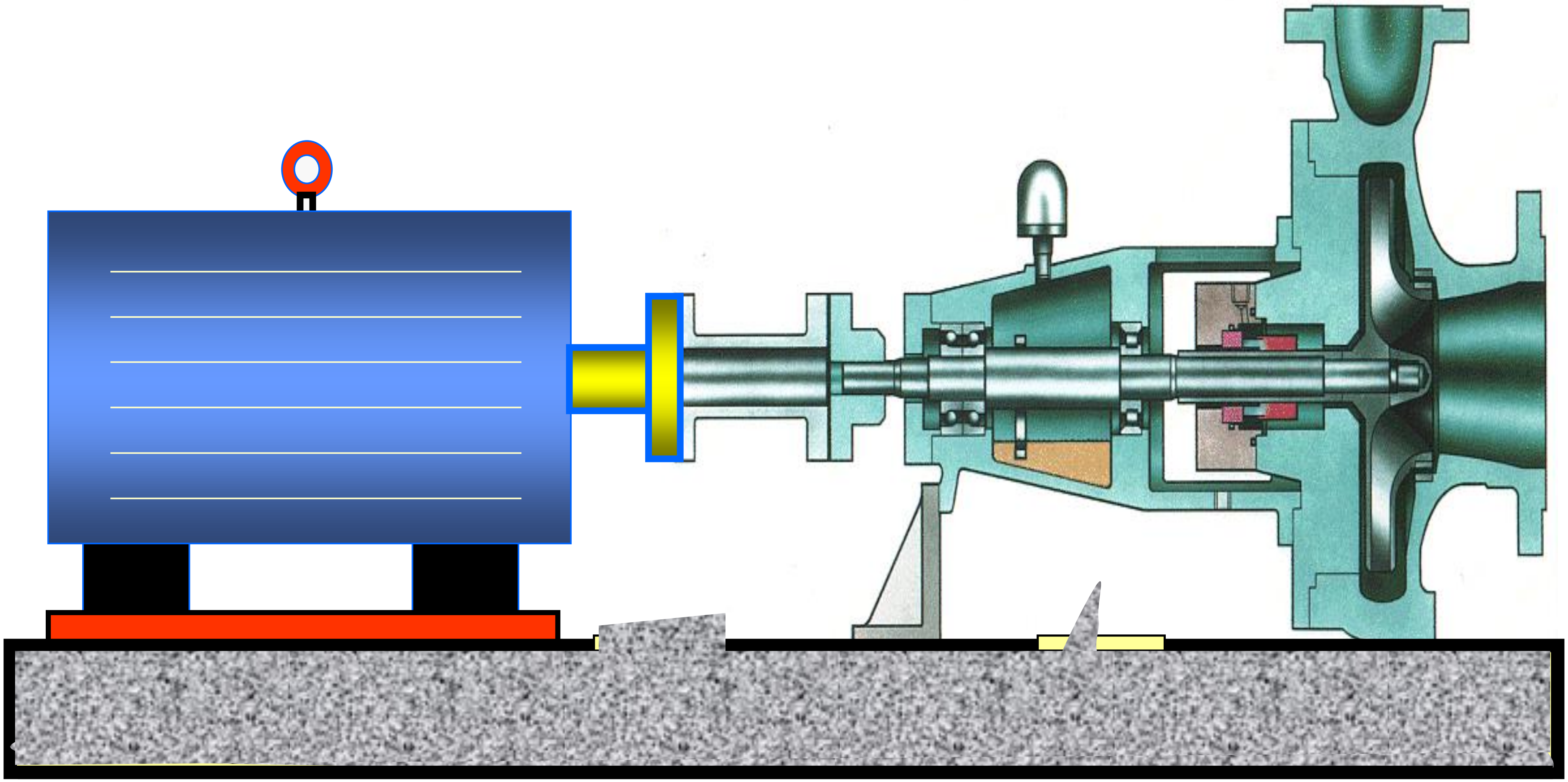
Vertically And Horizontally



It is collinear of two center lines

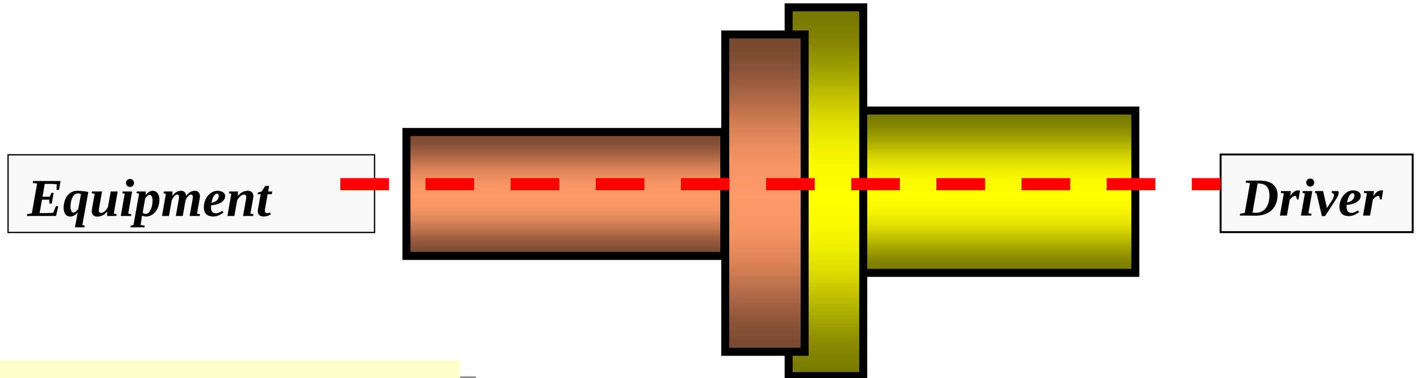


Pump Grouting



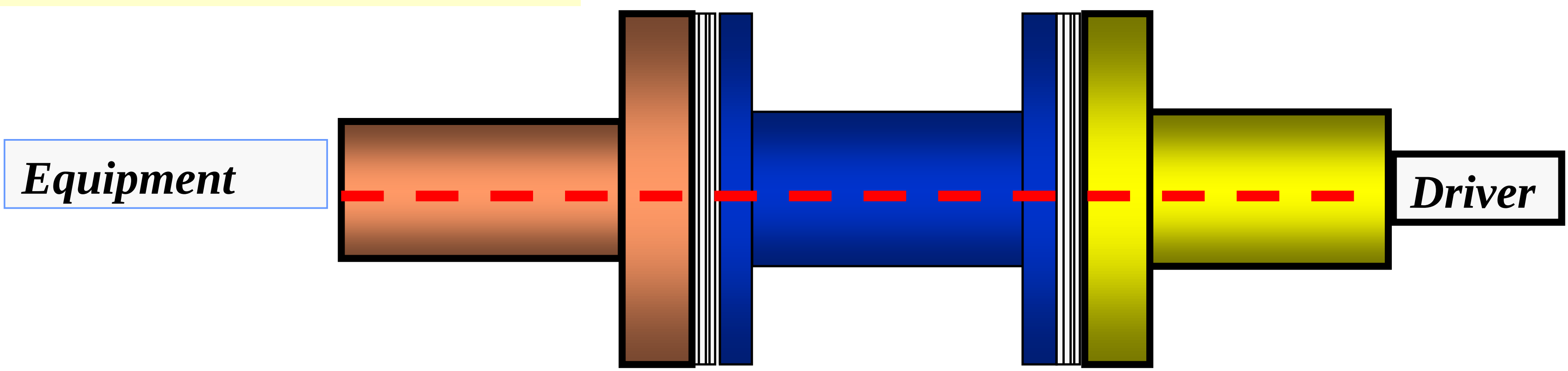
Special grouting concrete

1 -Rigid Couplings

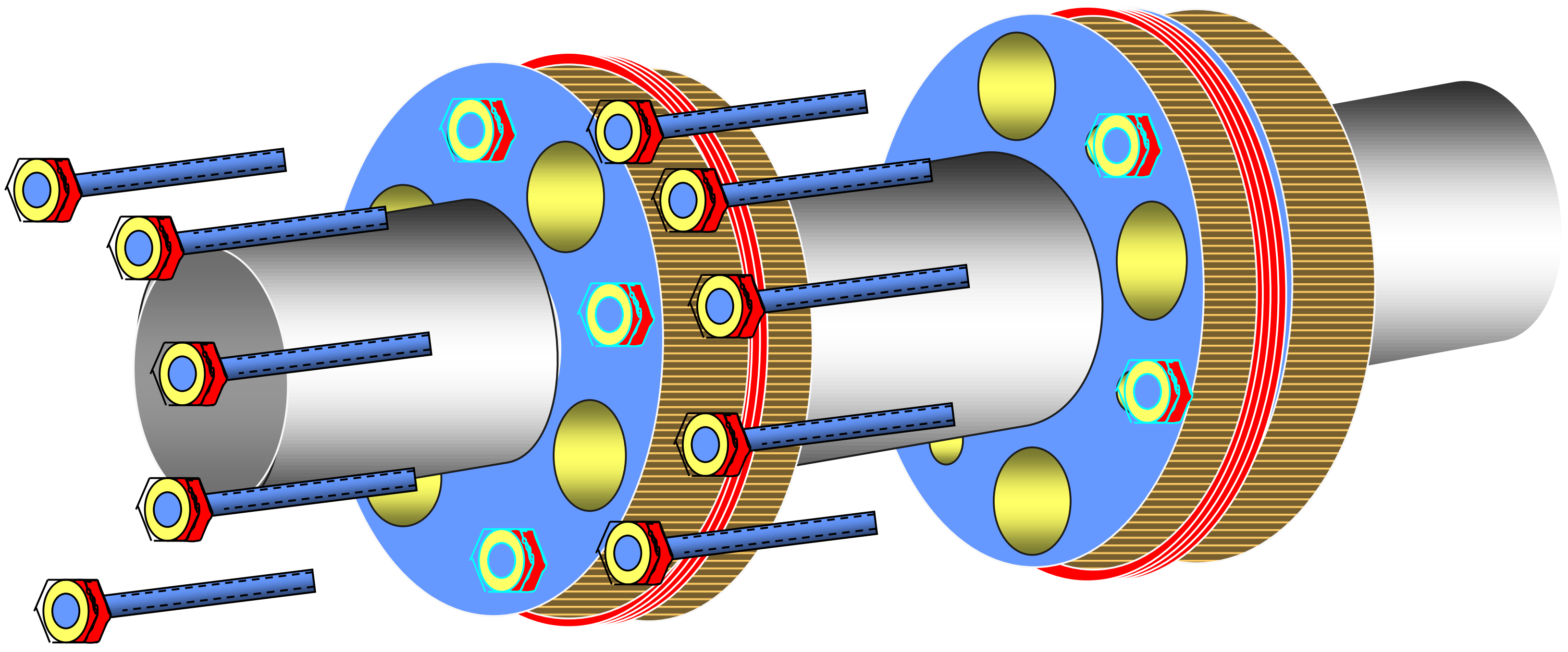


2 – Flexible Couplings

*Spacer with shims

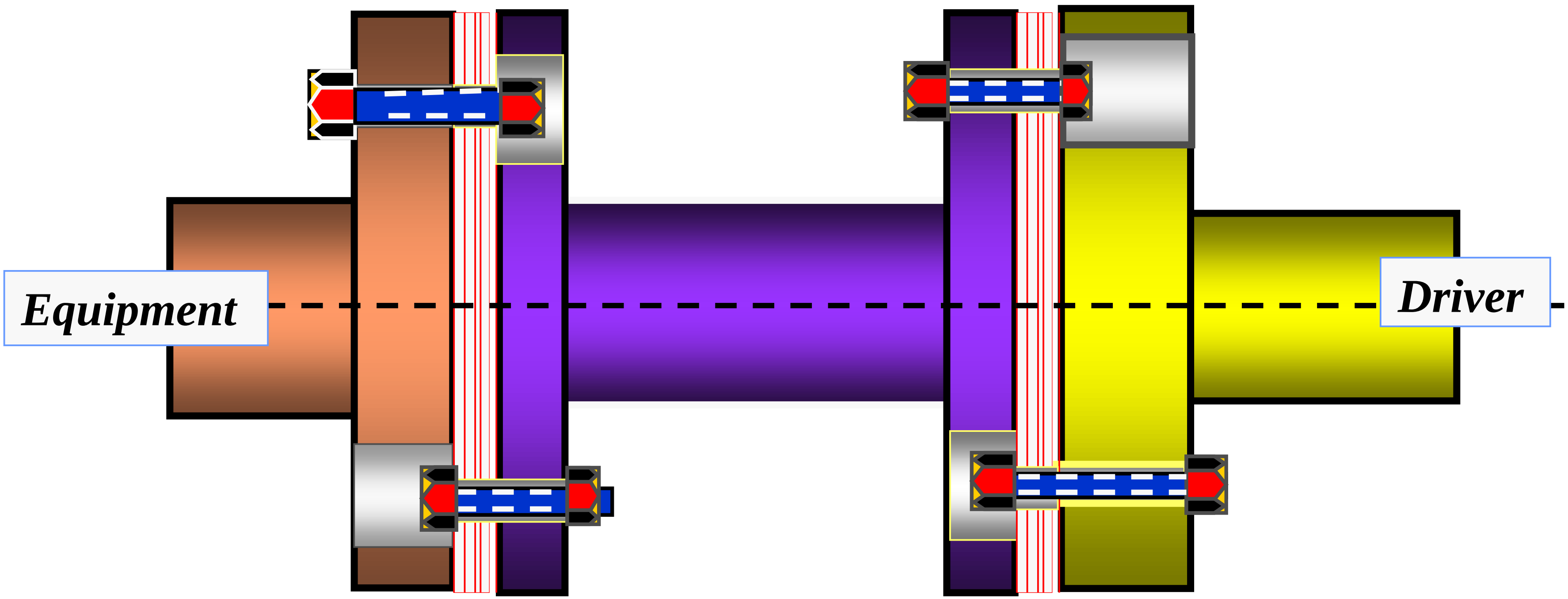


*Spacer with shims



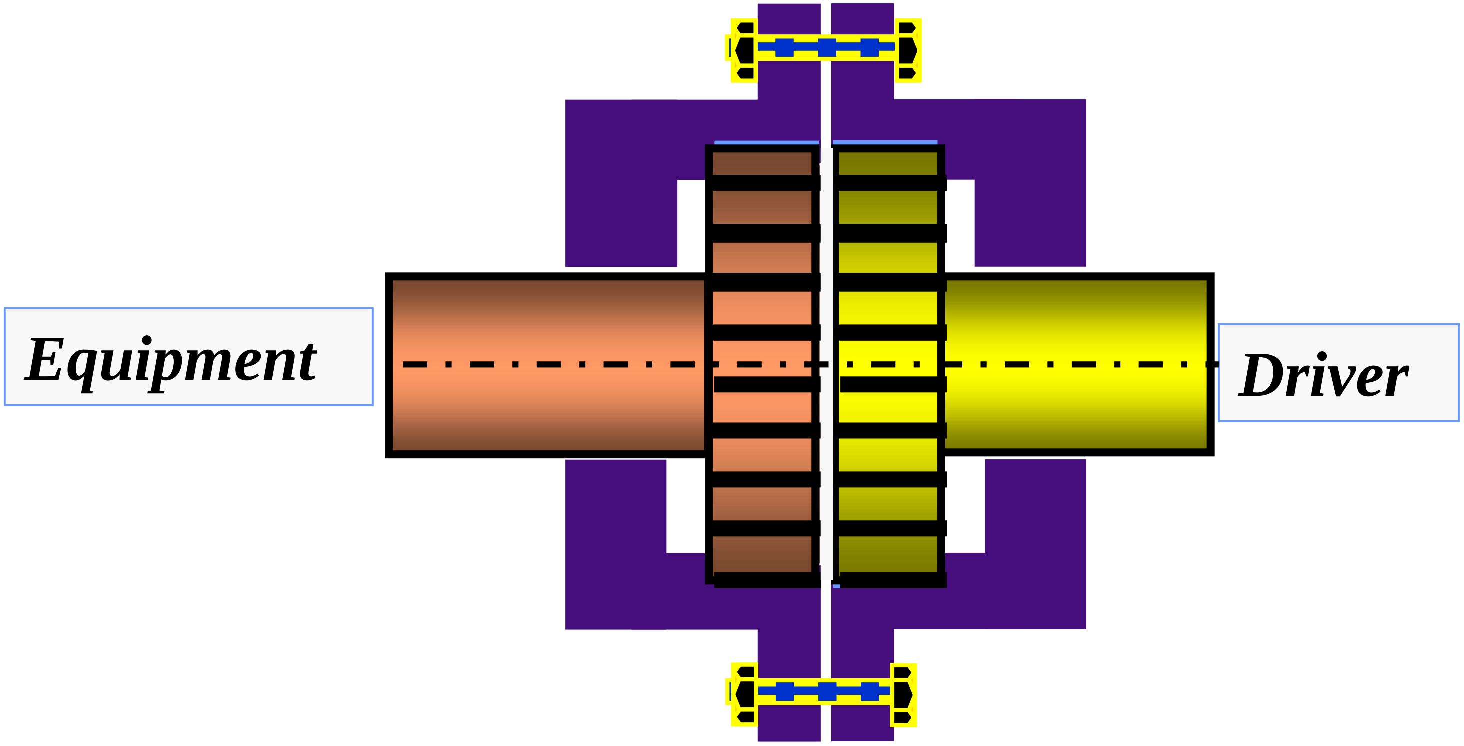
*Spacer with shims

Spacer is not connected directly to both hubs, but through the shims

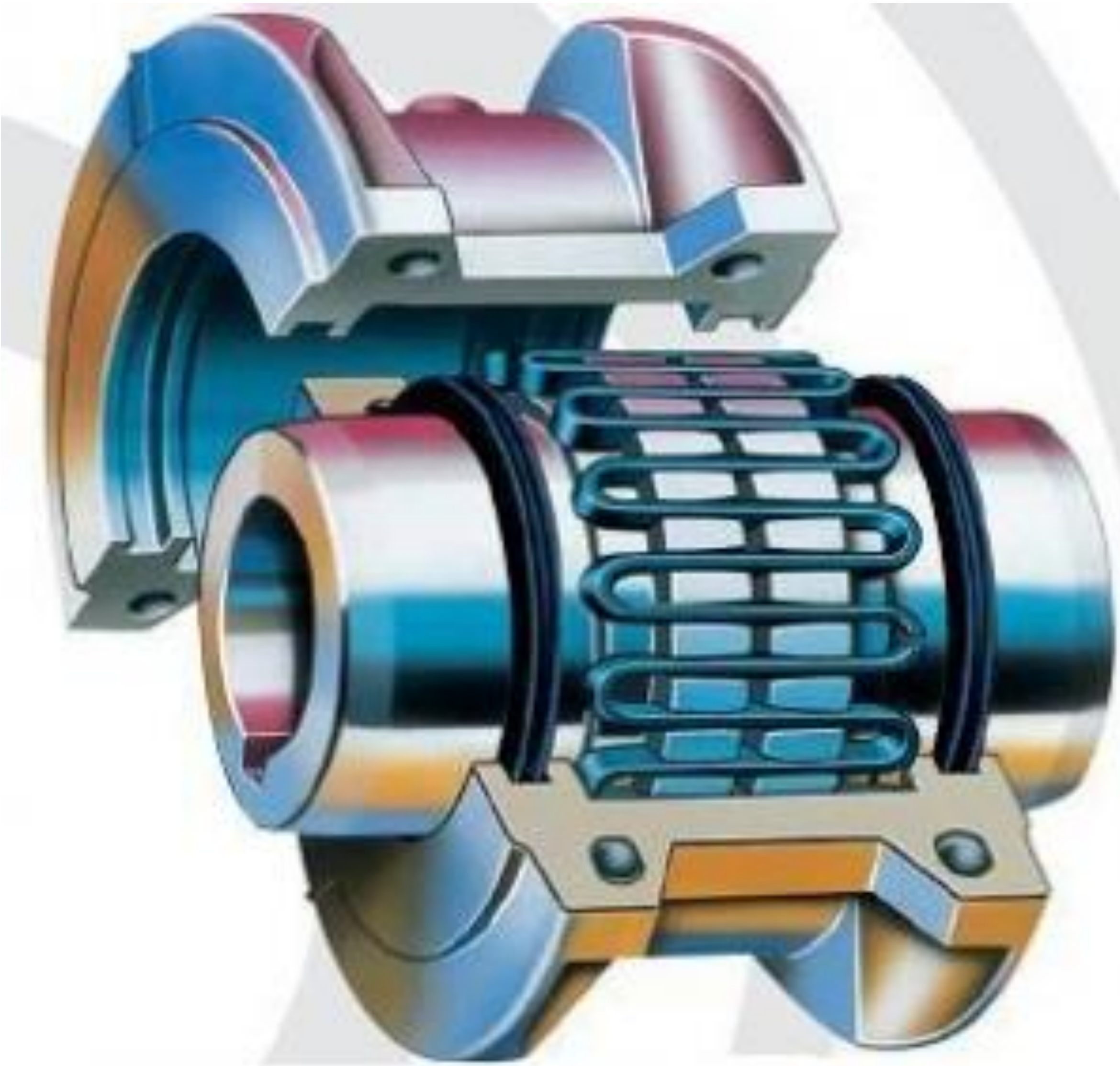


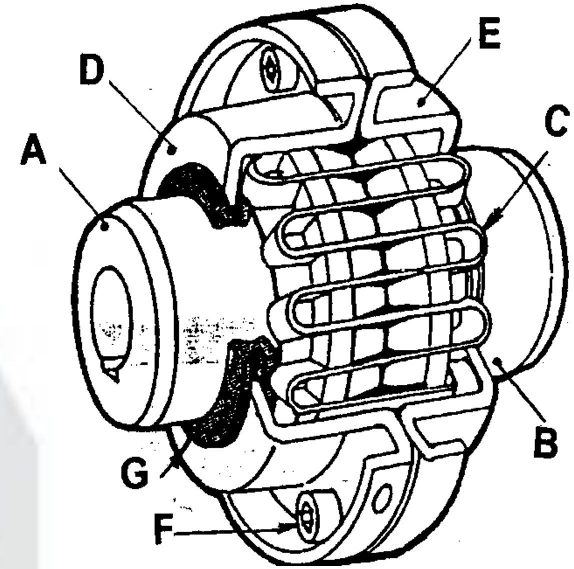
*Gear

*Gear

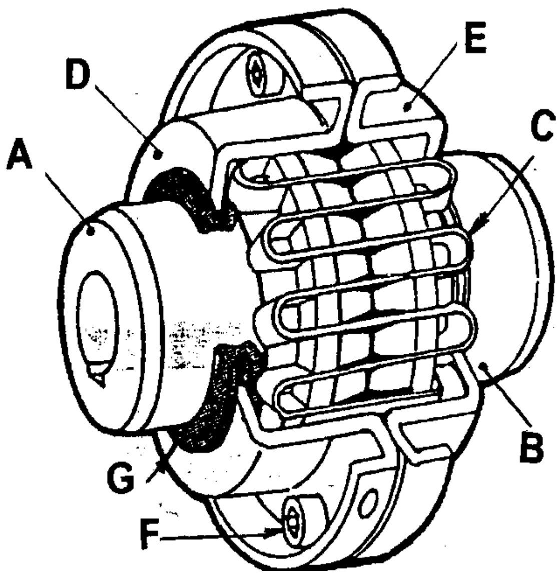


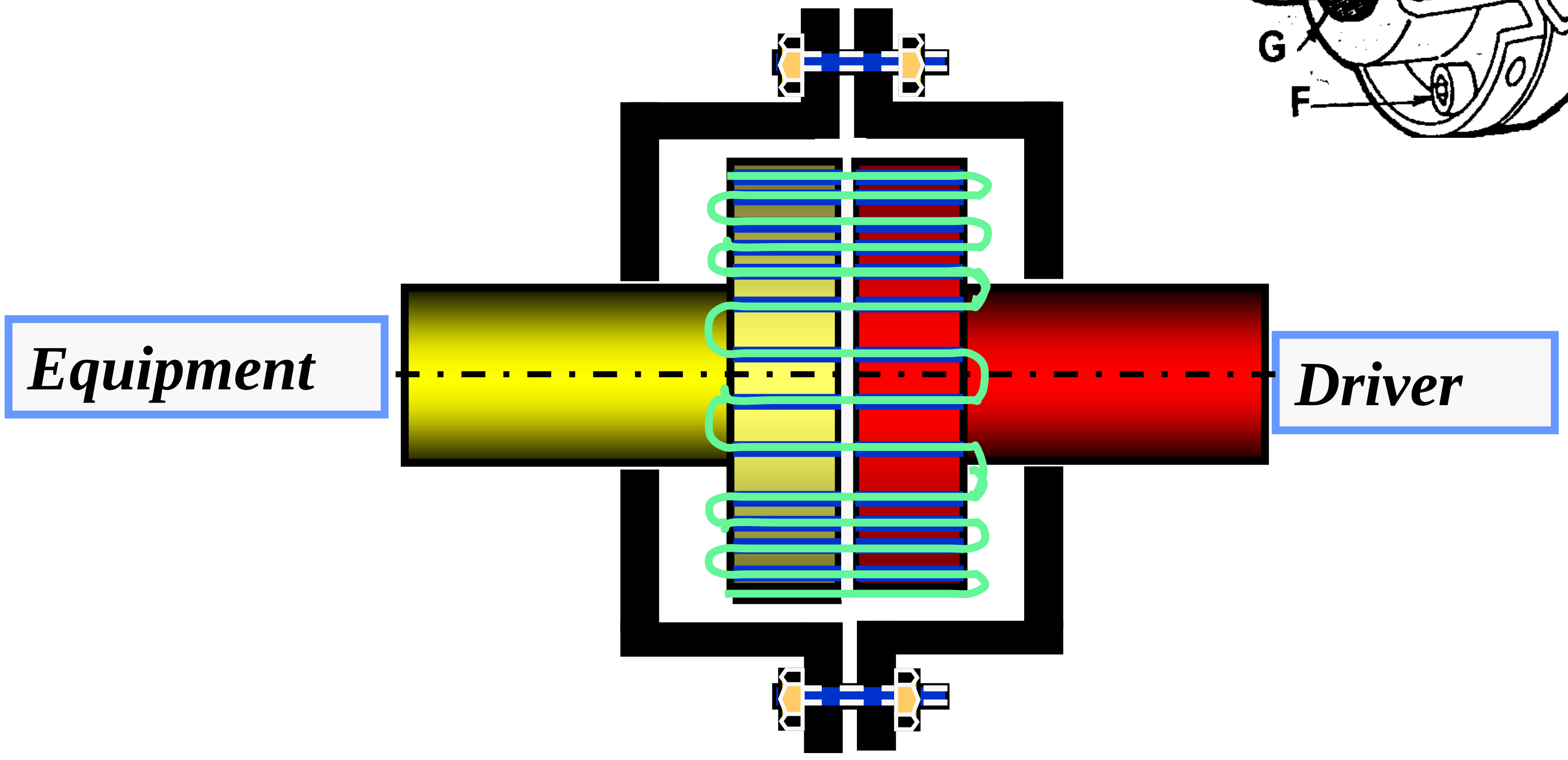
*Grid



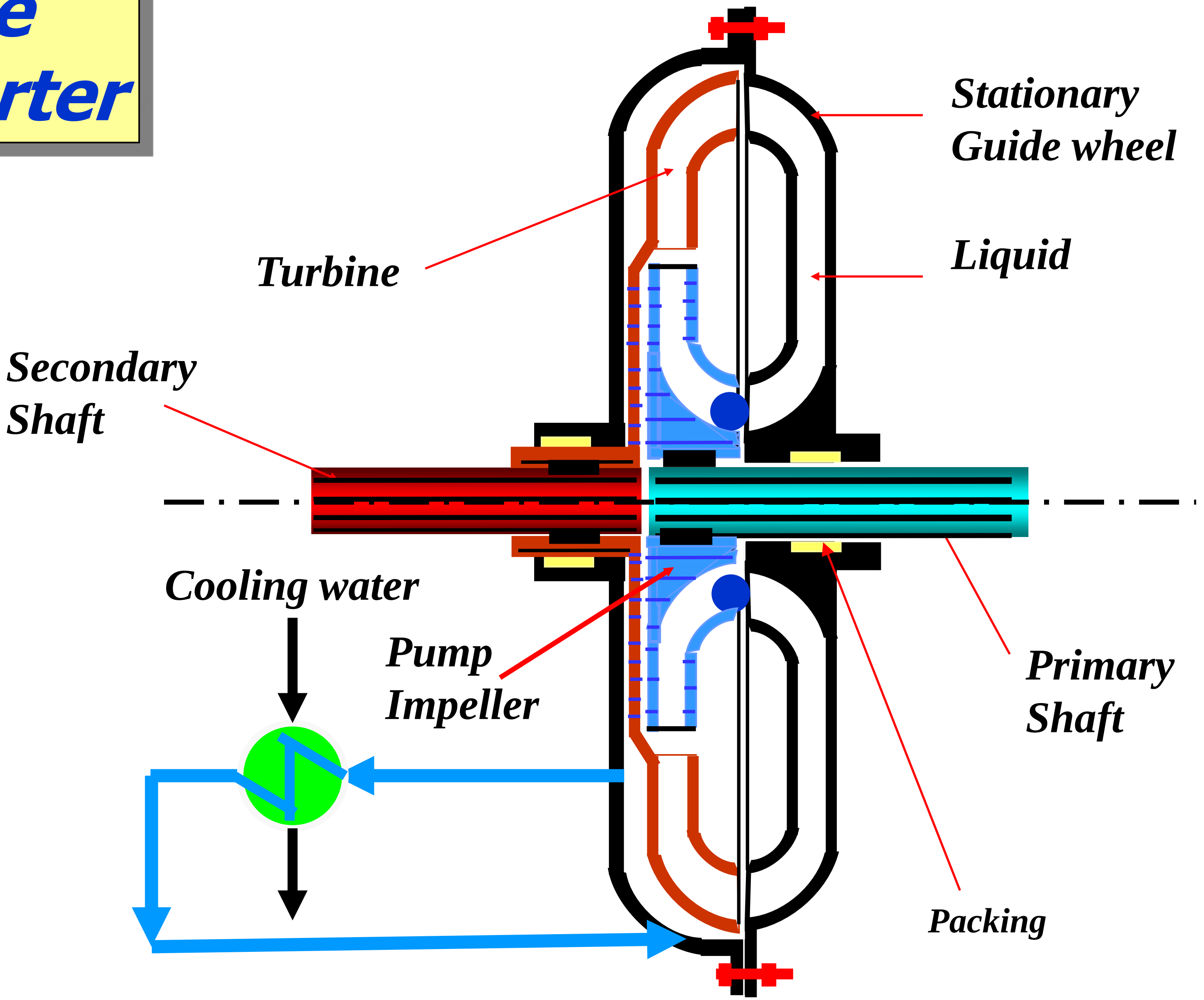


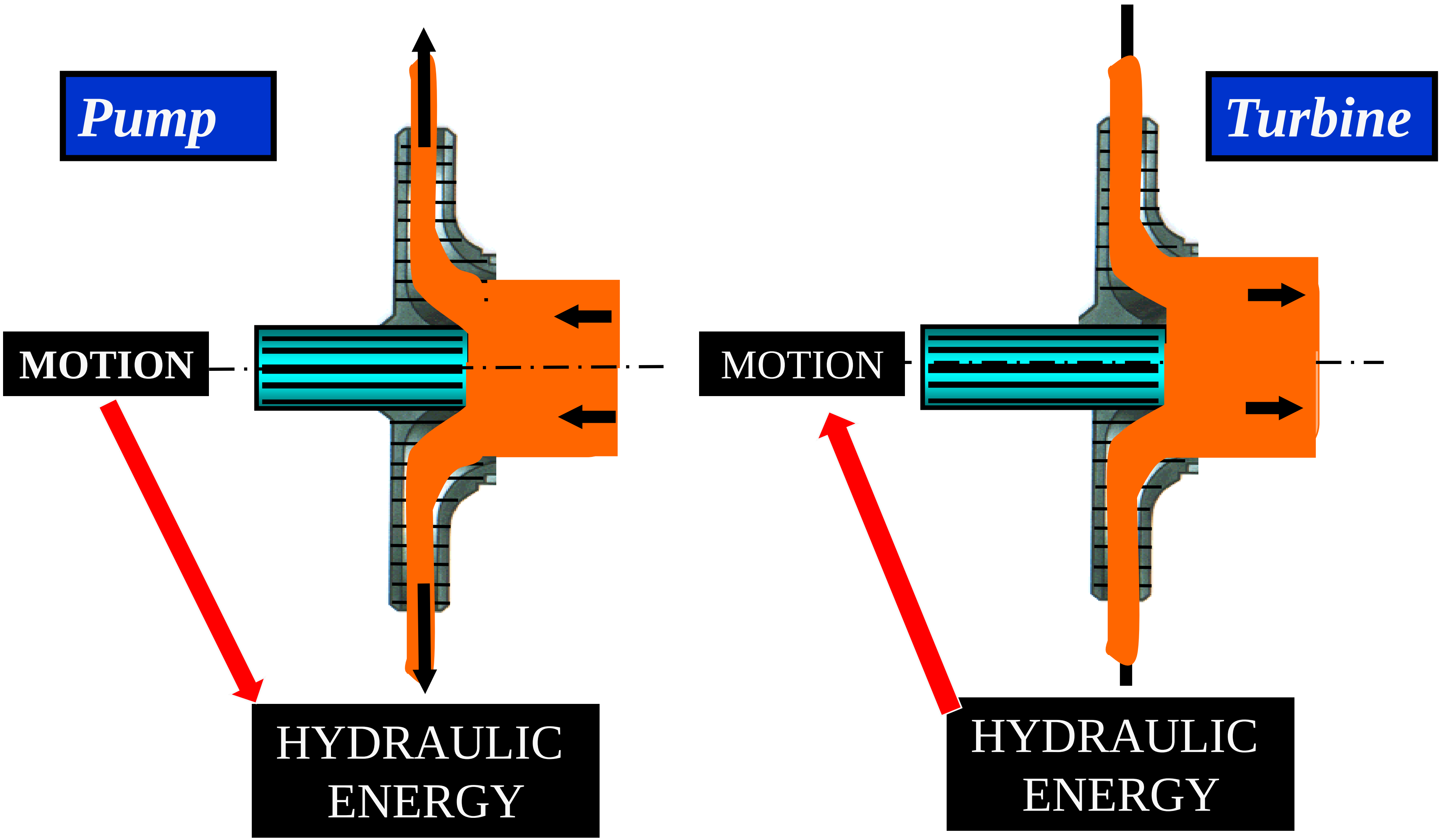
*Grid



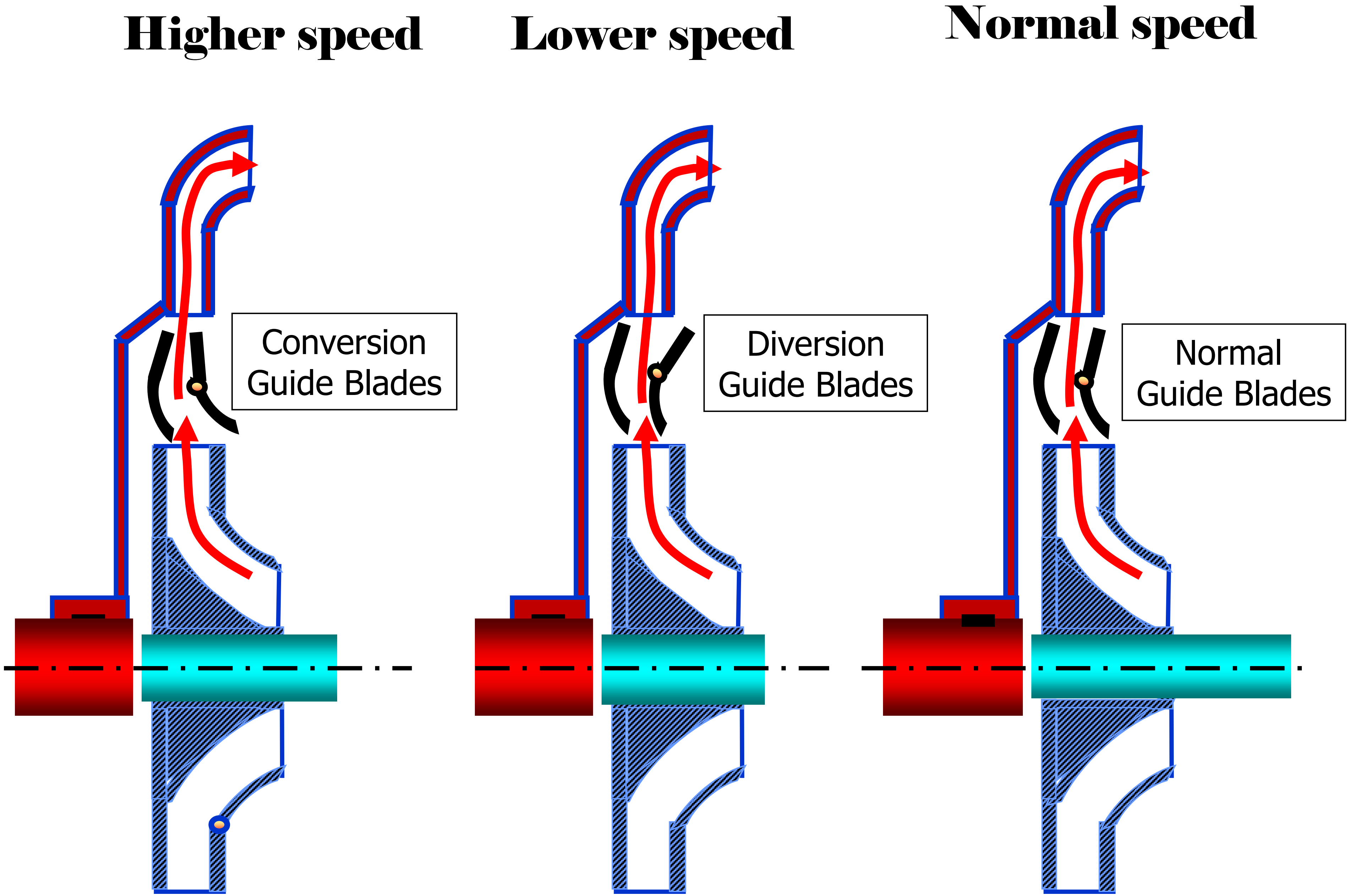


Torque converter



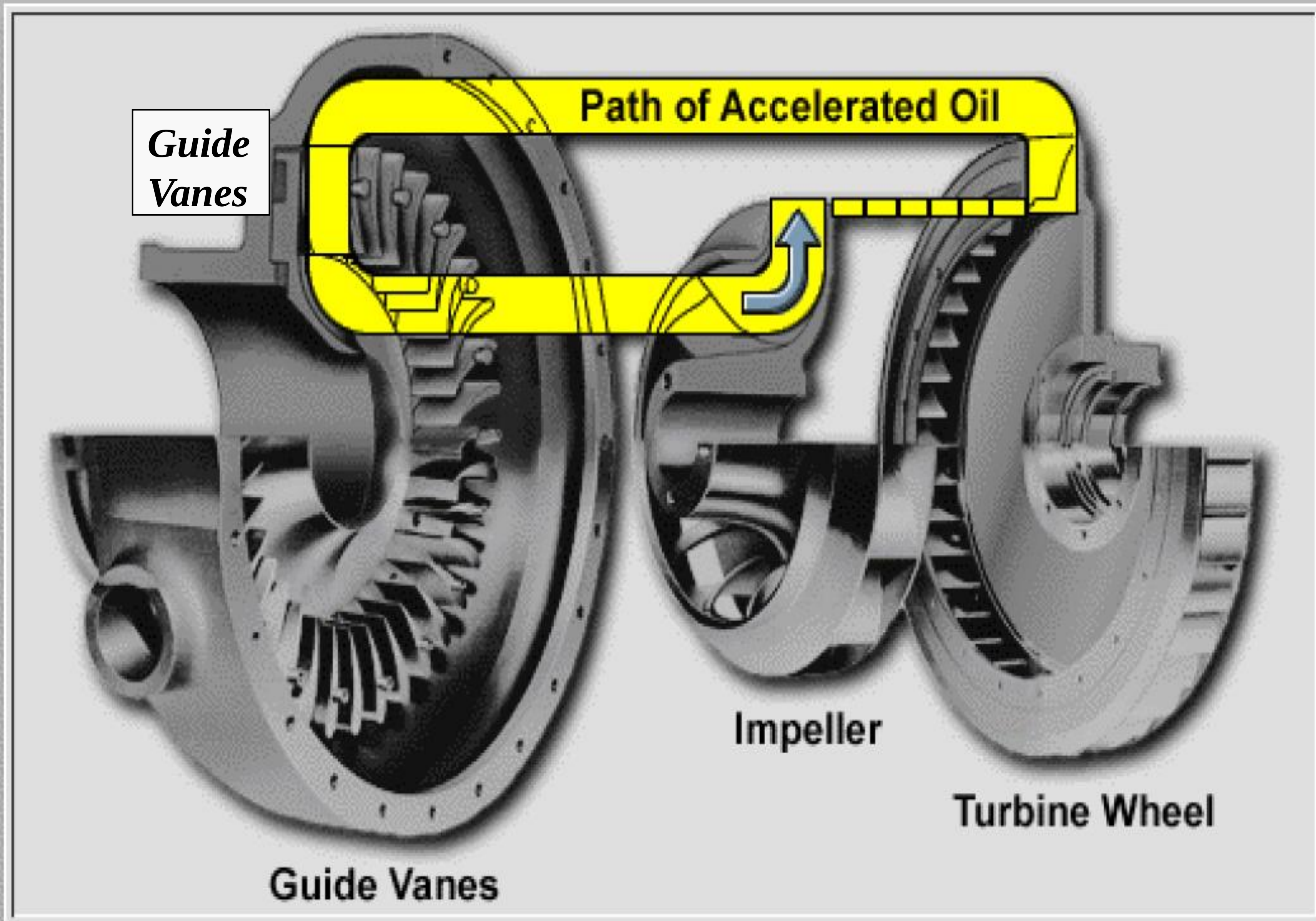


Pump
Turbine
MOTION
MOTION
HYDRAULIC ENERGY
HYDRAULIC ENERGY



Higher speed
Lower speed
Normal speed
Conversion Guide Blades
Diversion Guide Blades
Normal Guide Blades

Basic Torque Converter Design



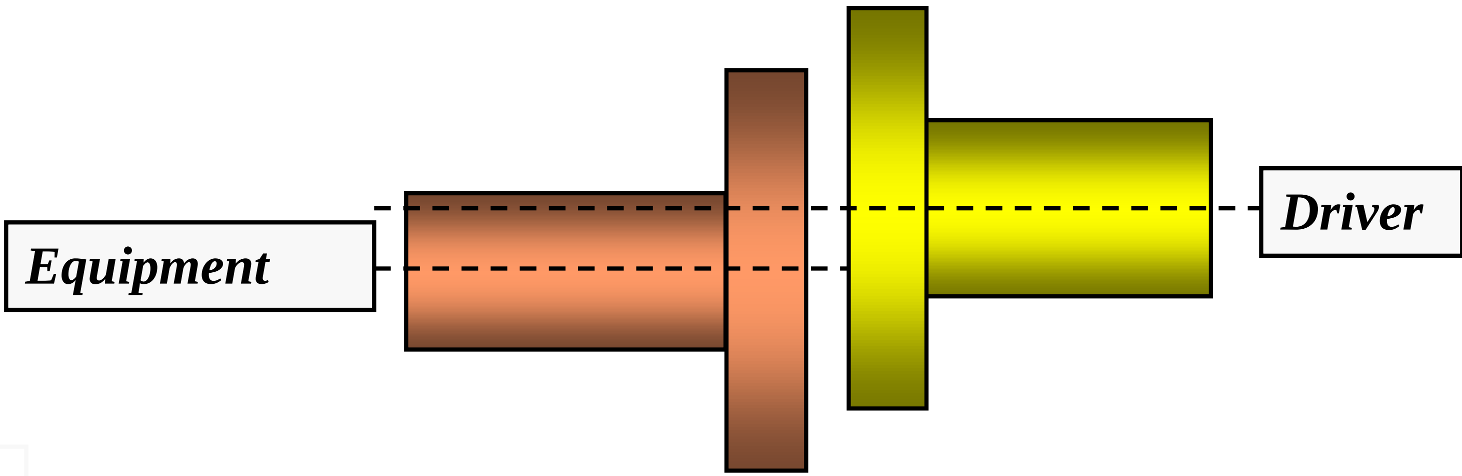
3- Alignment Preparation check list

Parallel misalignment

Vertical

OR

Horizontal

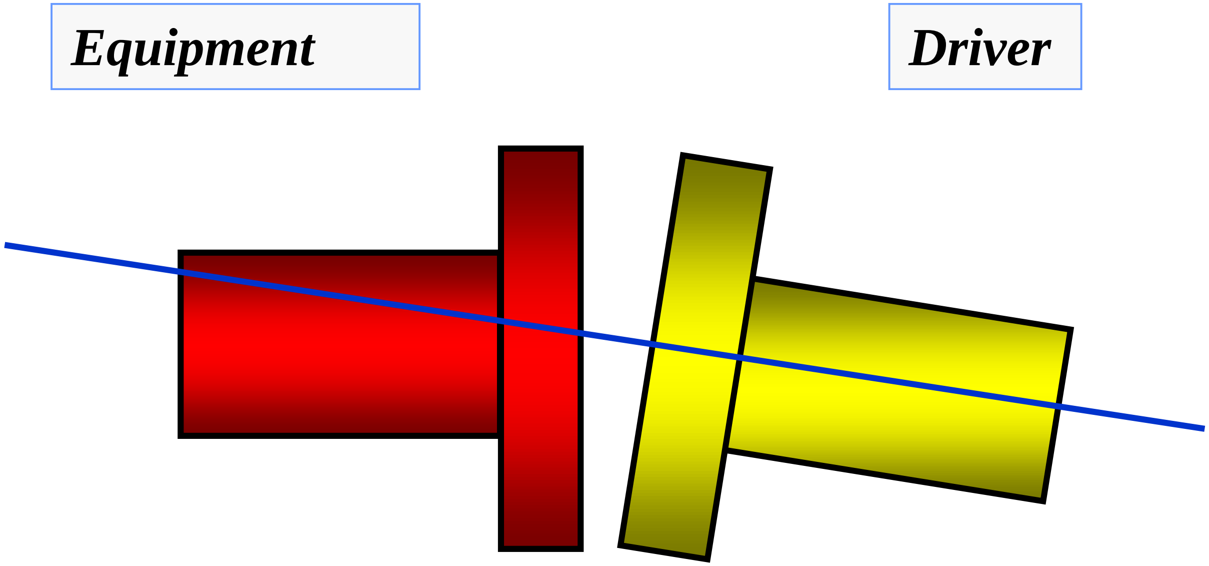


Angular Misalignment

Vertical

OR

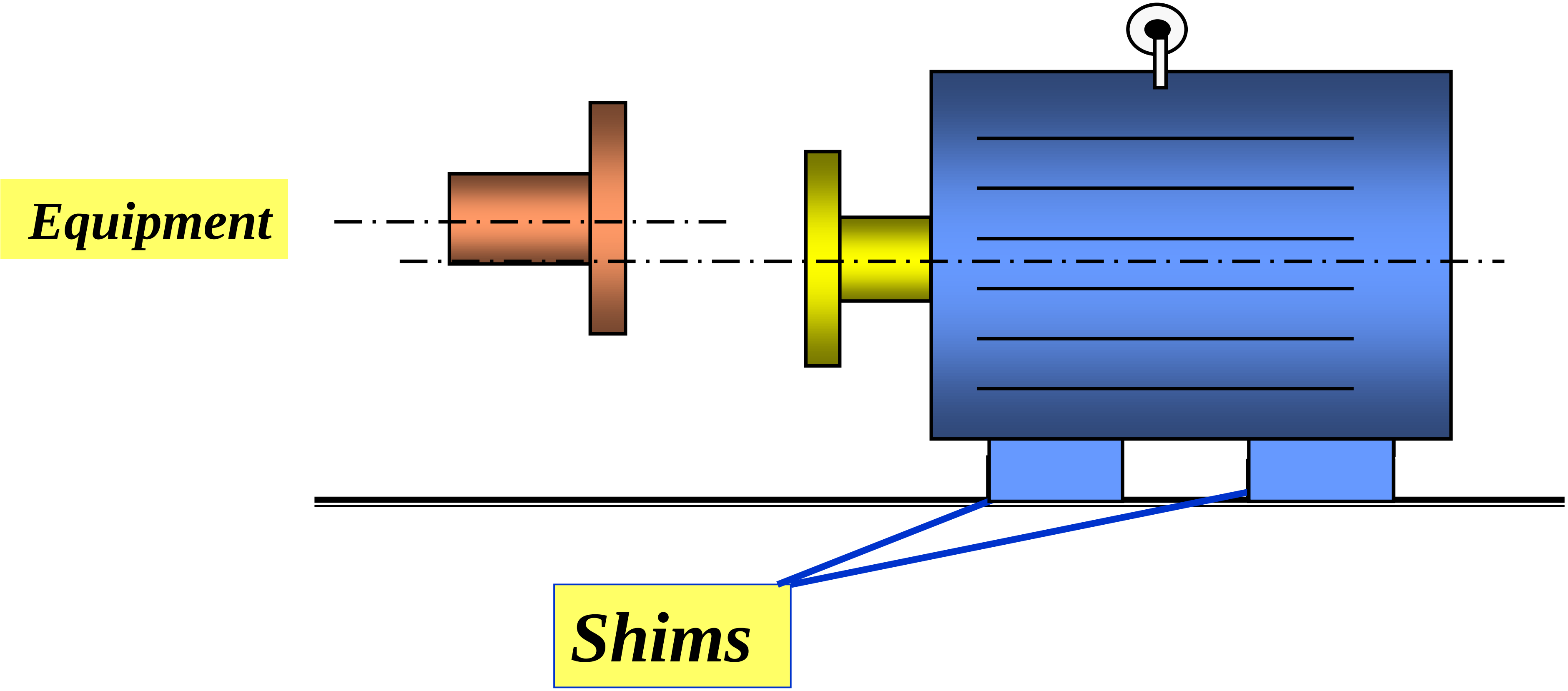
Horizontal



Correcting of Misalignment

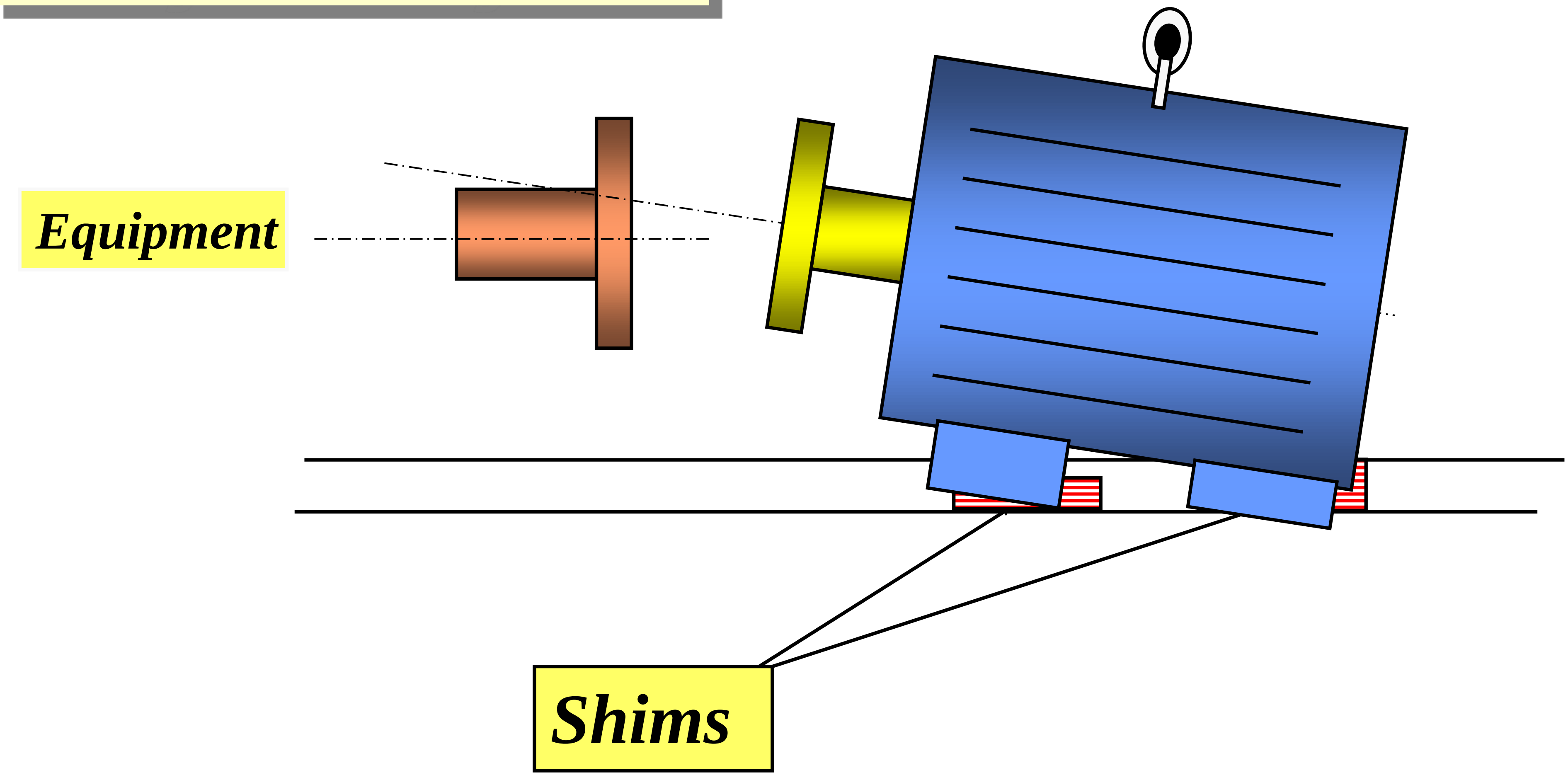
I- Vertical Plane

A- Parallel Misalignment



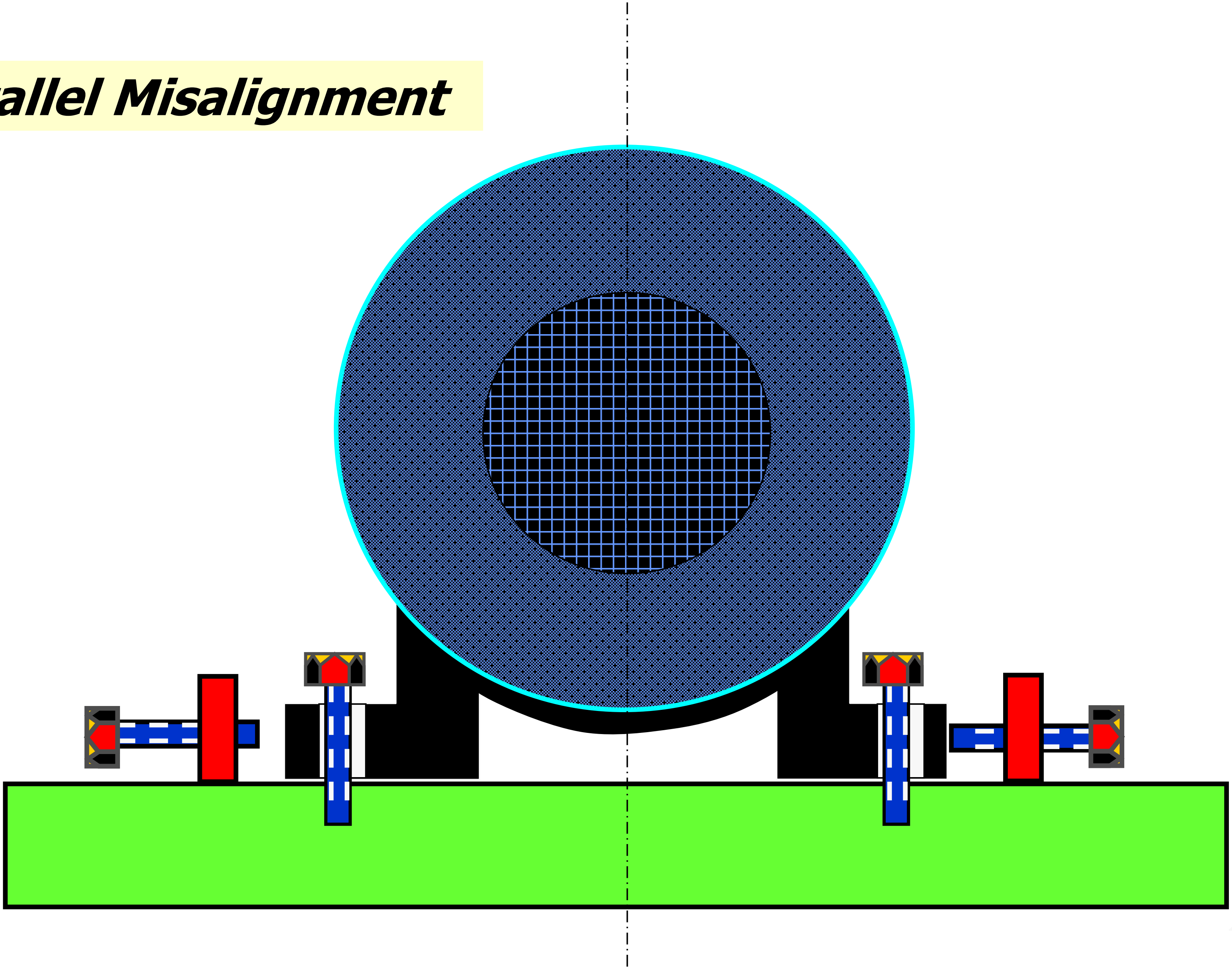
I- Vertical Plane

B- Angular Misalignment

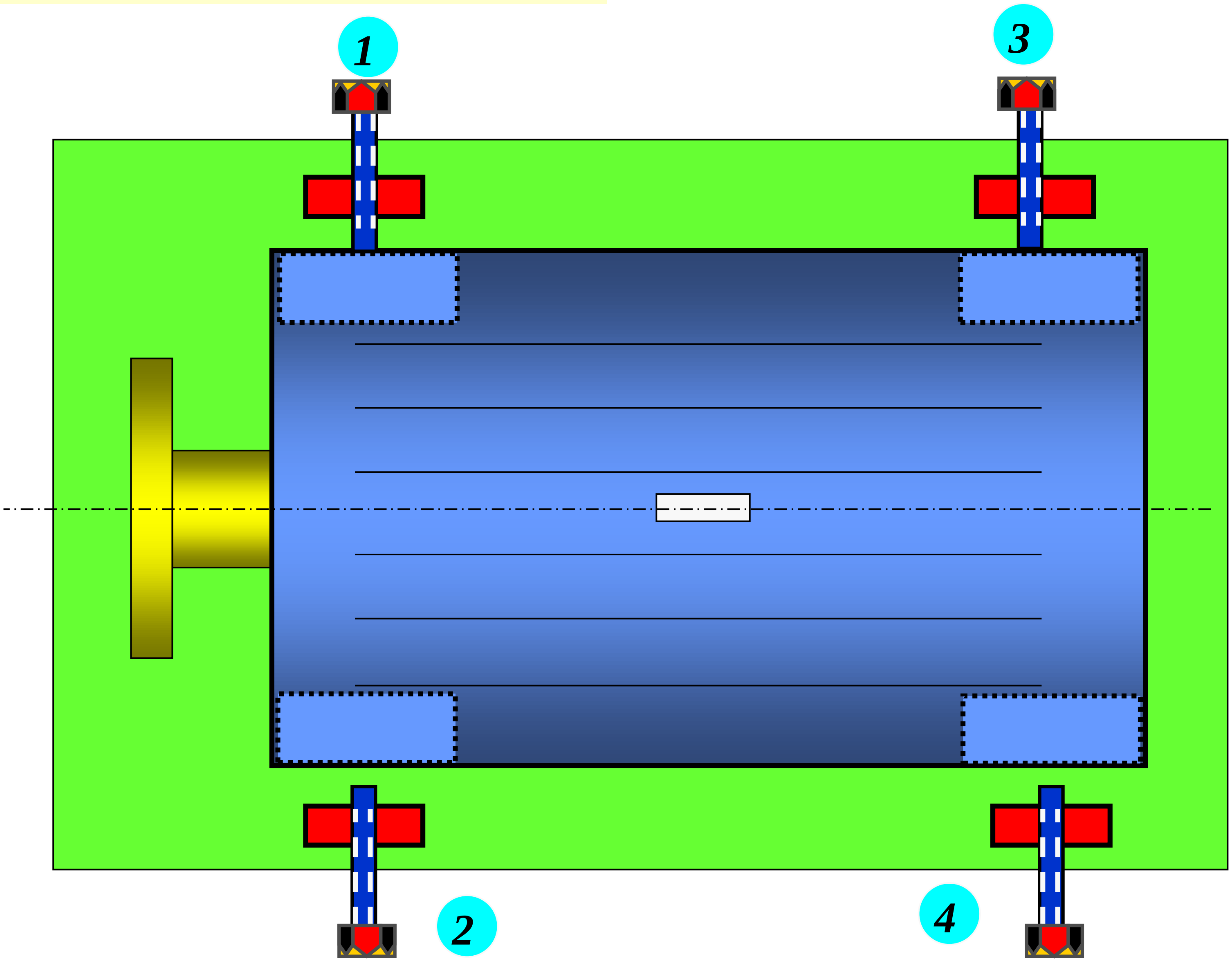


II- HORIZONTAL PLANE

A- Parallel Misalignment

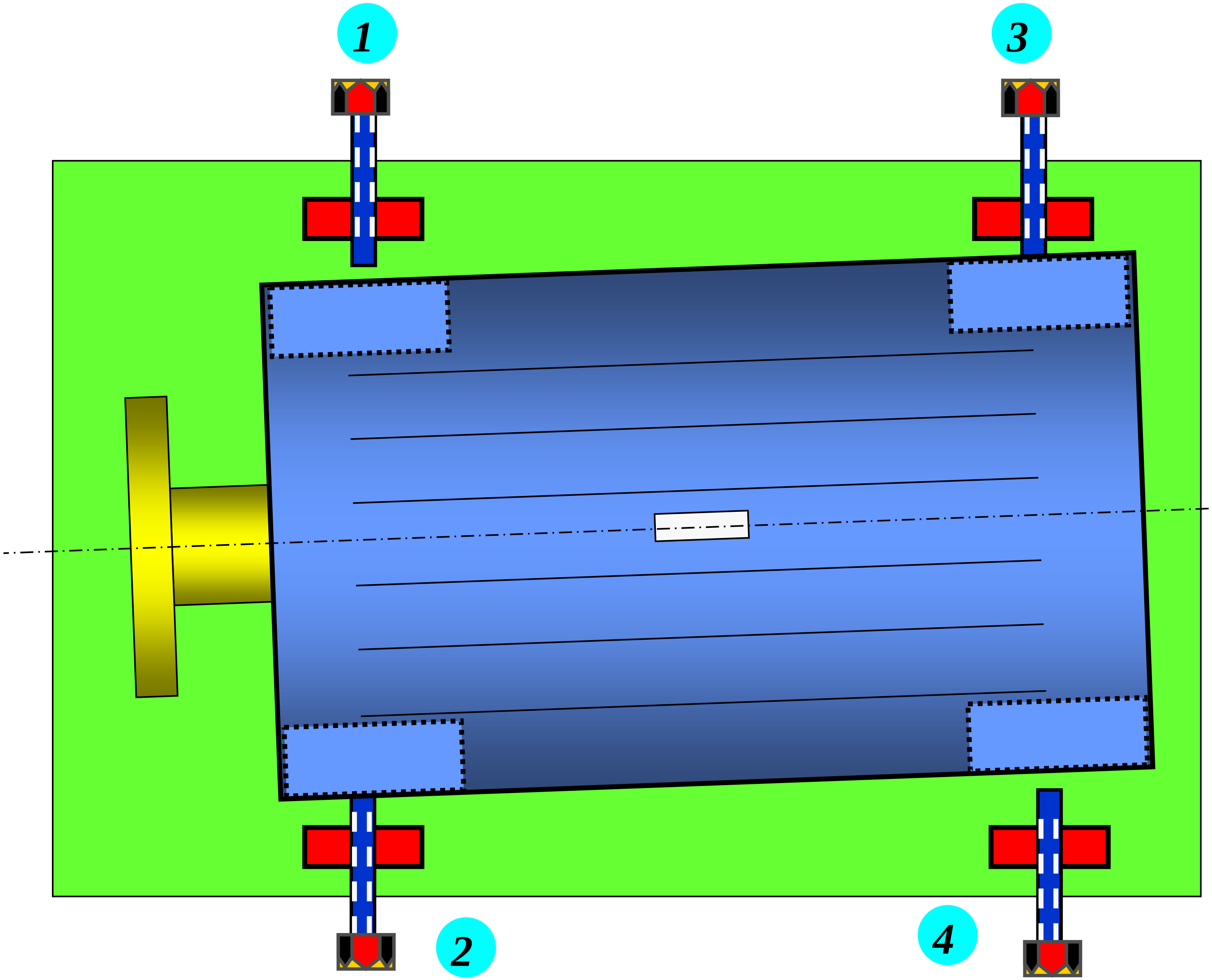


A- Parallel Misalignment

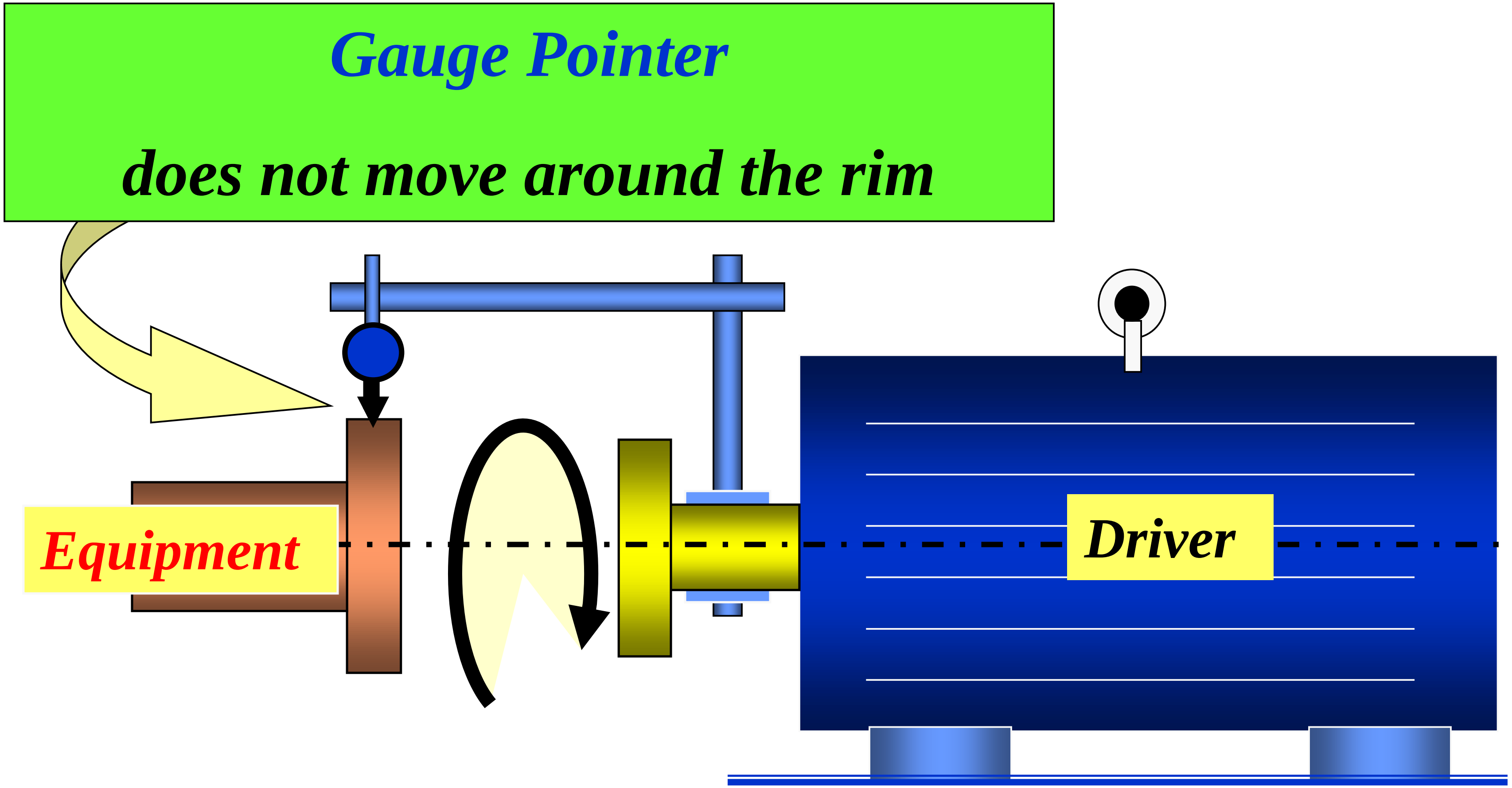


II- HORIZONTAL PLANE

B- Angular Misalignment

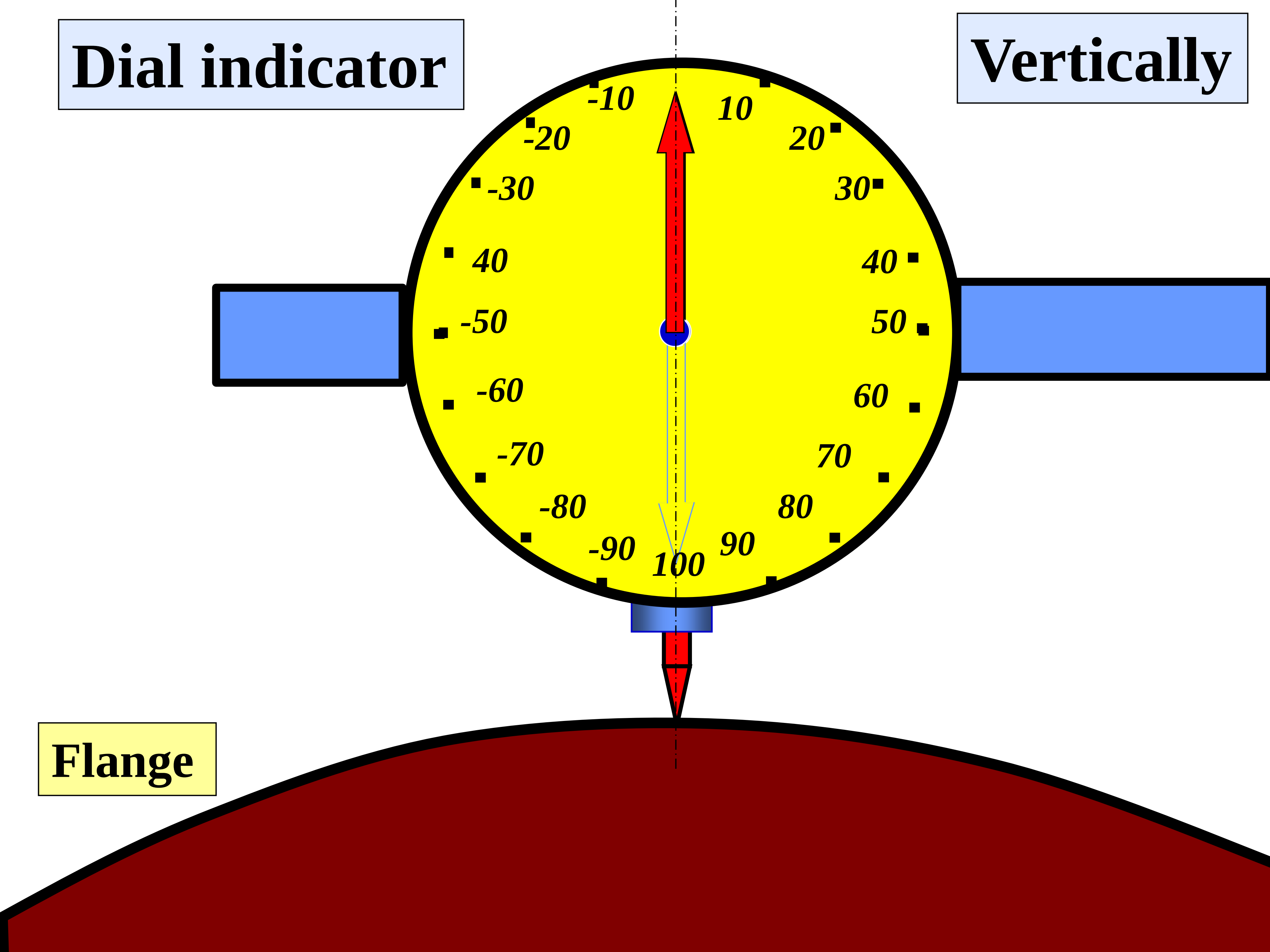


How To Do Alignment



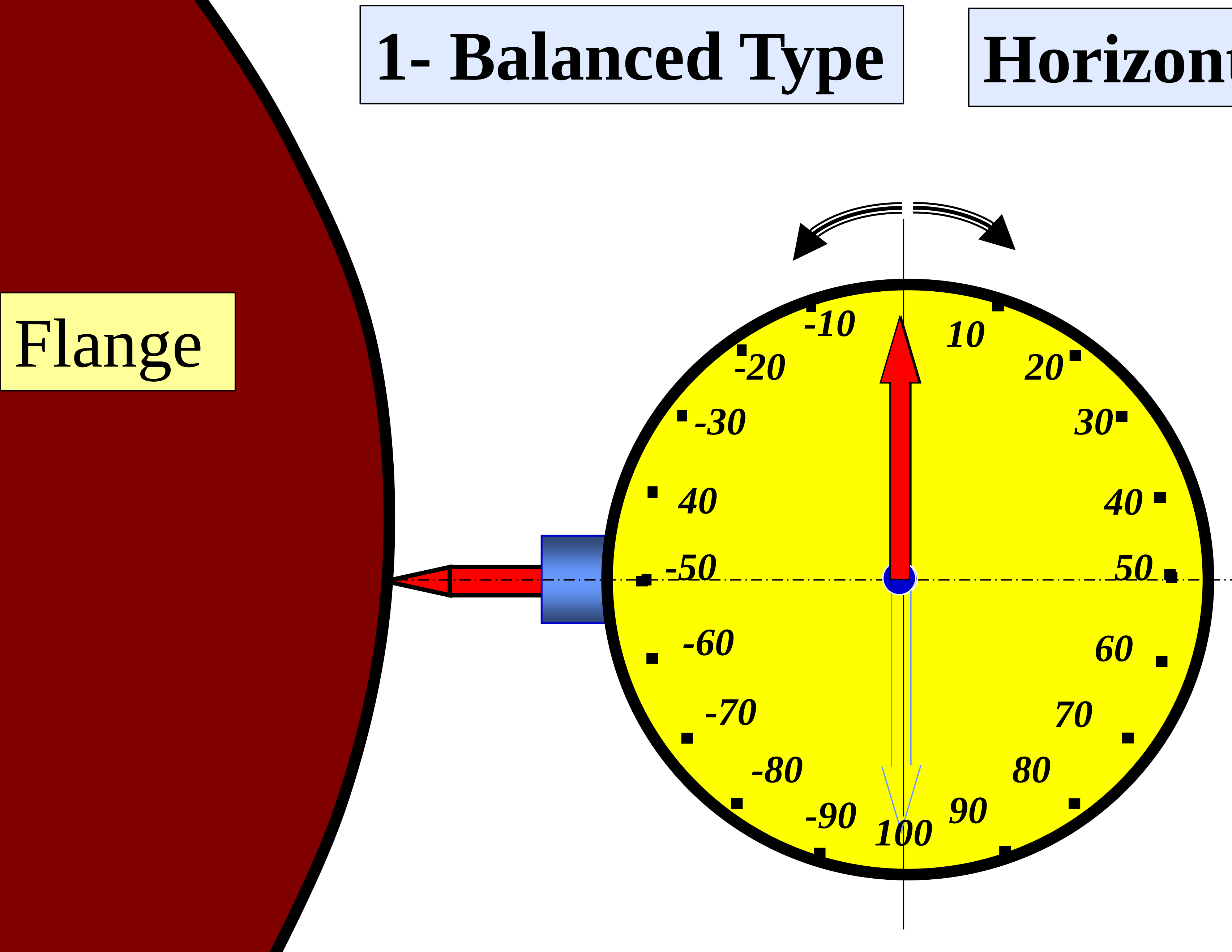
Motor and Equipment shaft

Rotate in the same time


Dial indicator
Vertically
-10
10
-20
20
-30
30
40
40
-50
50
-60
60
-70
70
-80
80
-90
90
100
Flange

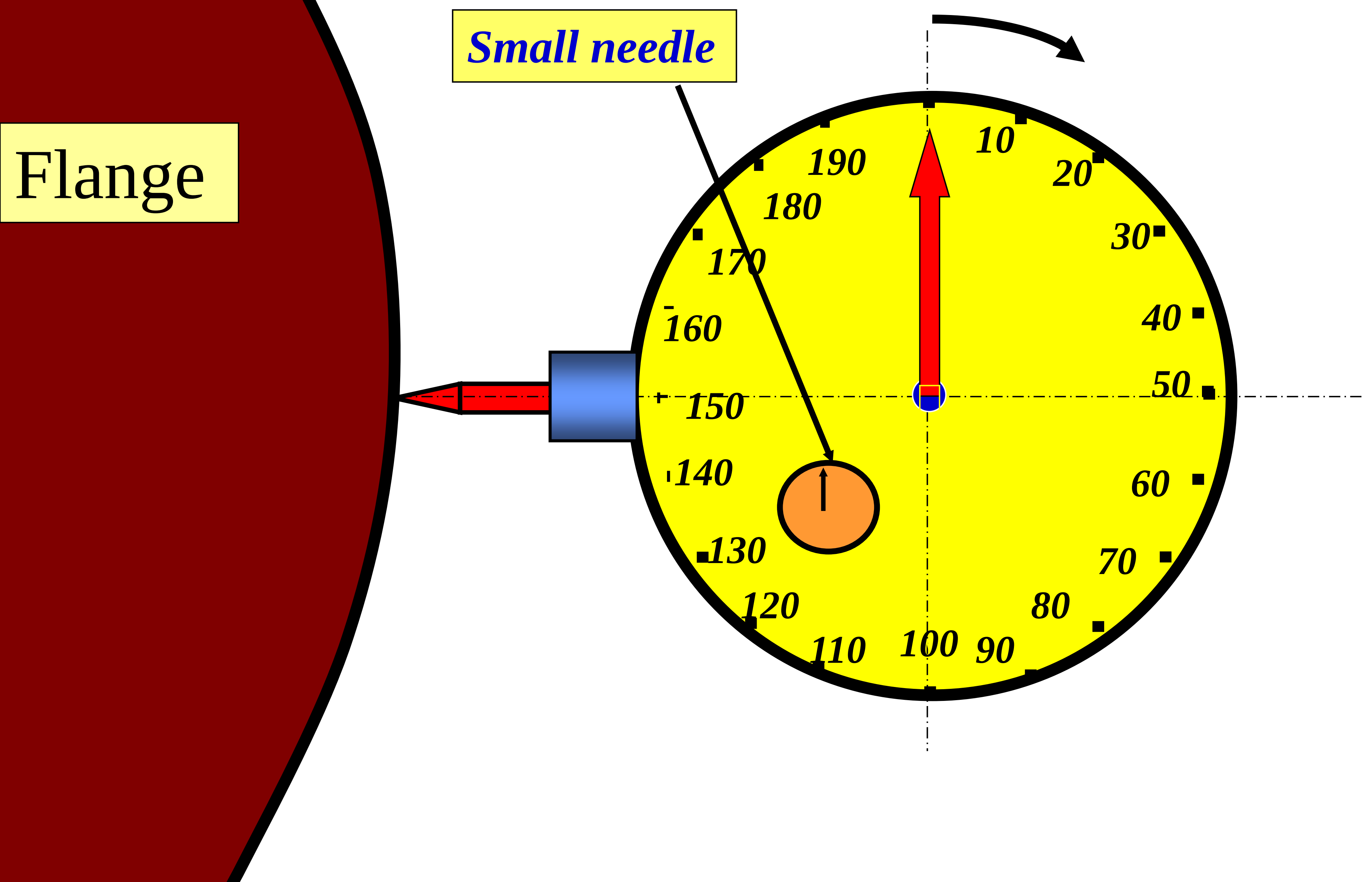
1- Balanced Type

Horizontally



Dial indicators Types and Functions

2 - Continuous Type

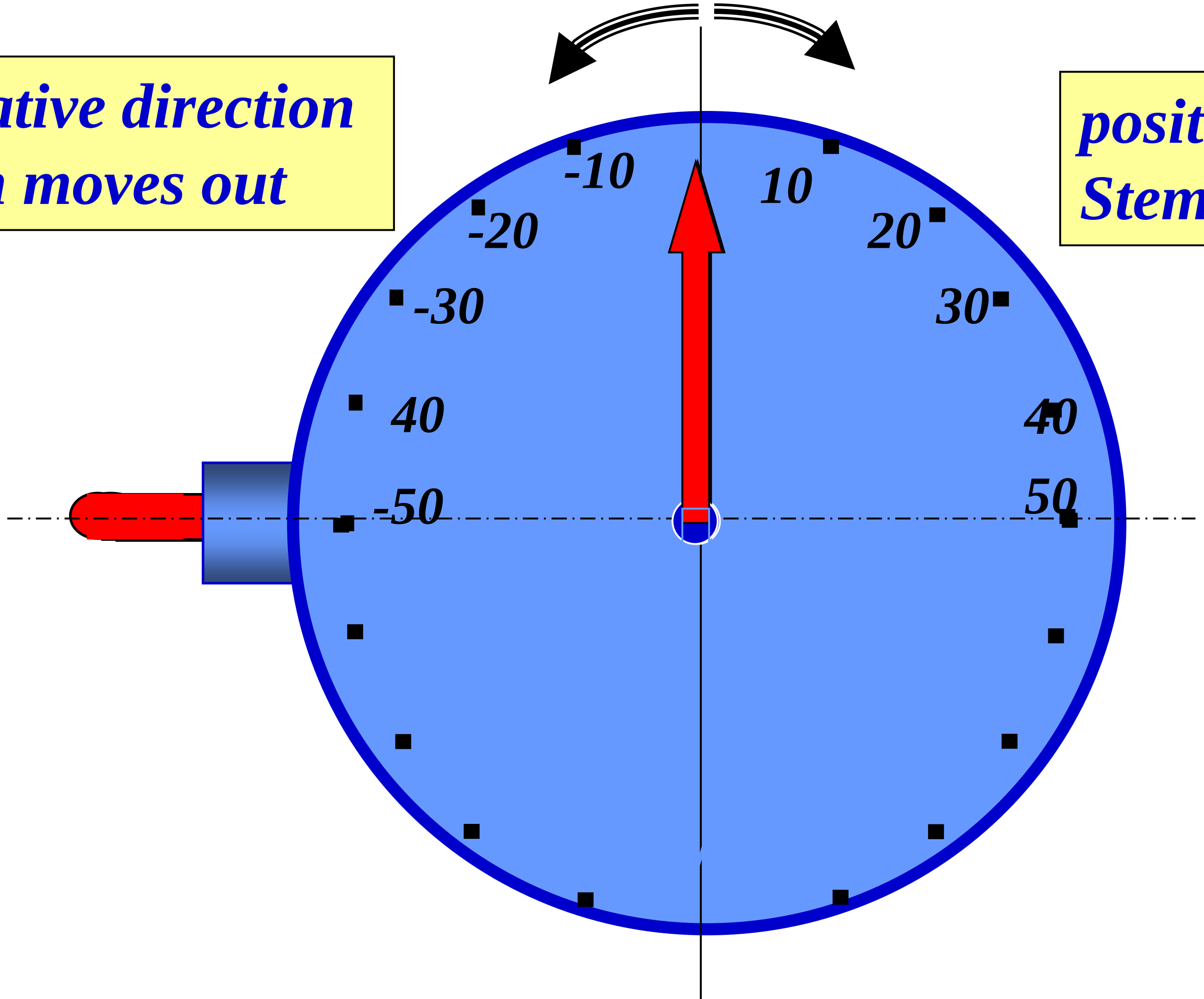


Dial indicators Types and Functions

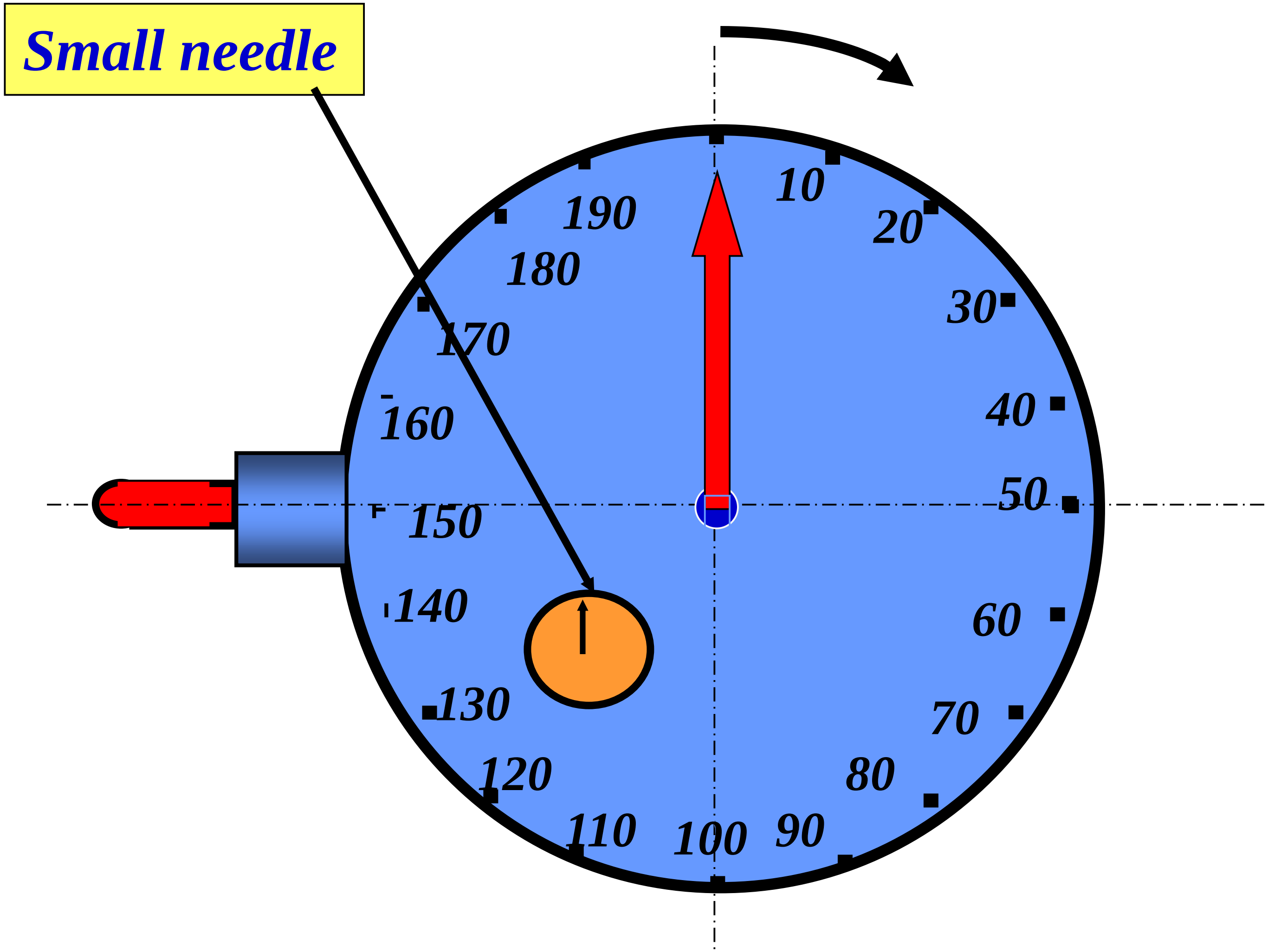
1- Balanced-Type

Negative direction
Stem moves out

positive direction
Stem moves in



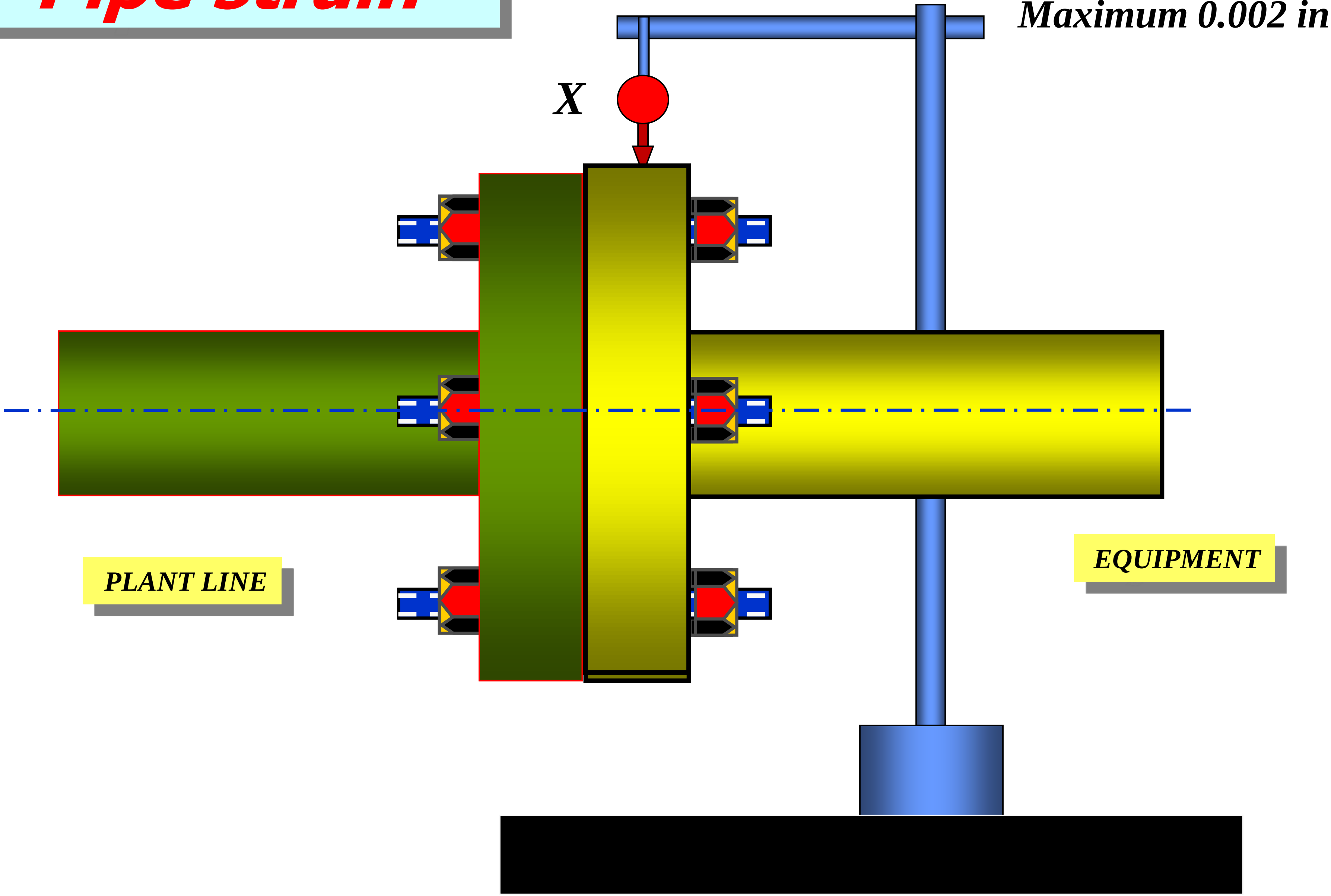
2 - Continuous Type



Measure and correct

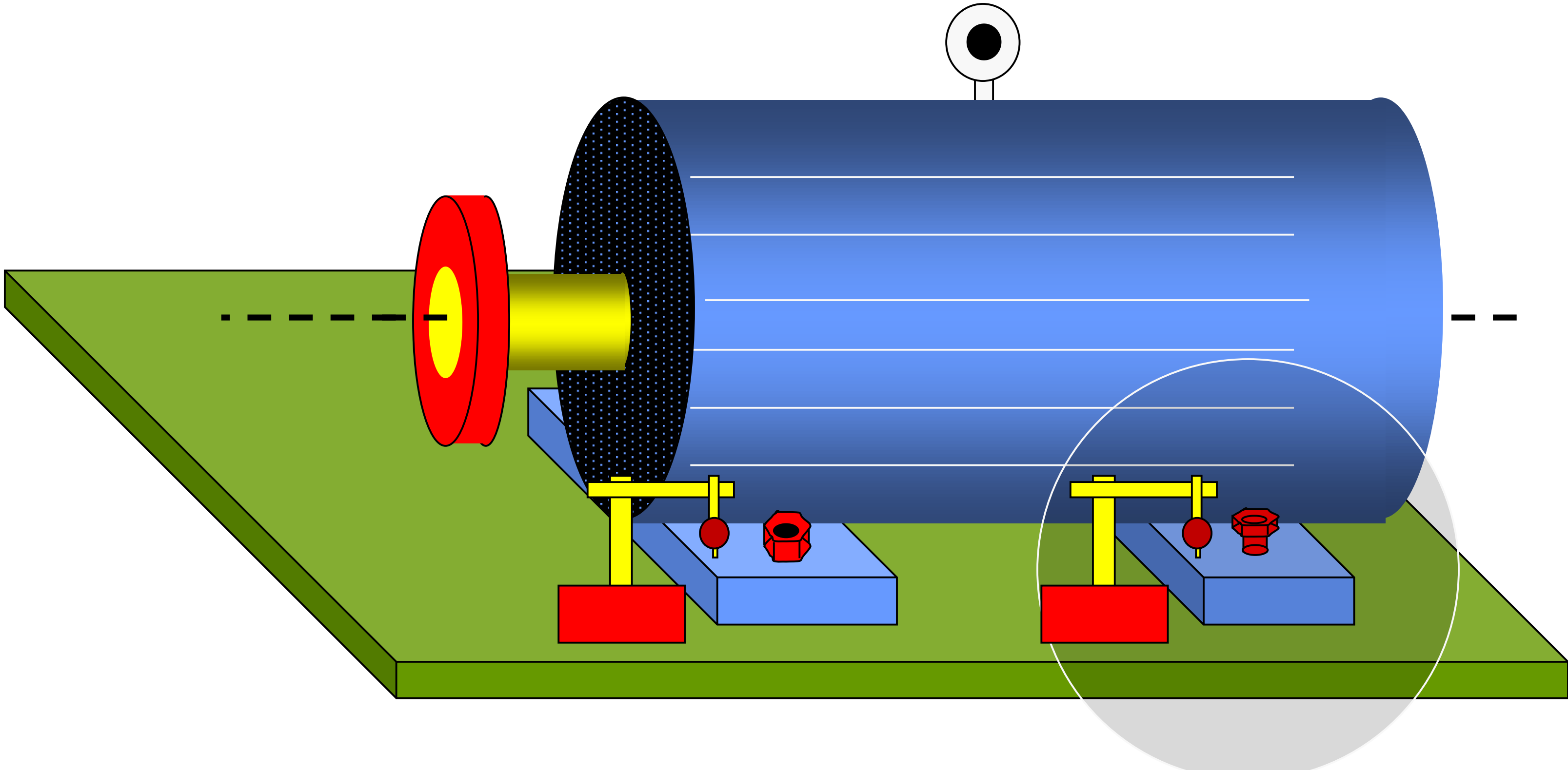
* Pipe strain
* Soft foot
* Run out
* Thermal growth
* Mechanical centre
* Magnetic centre

* Pipe strain



* Soft foot

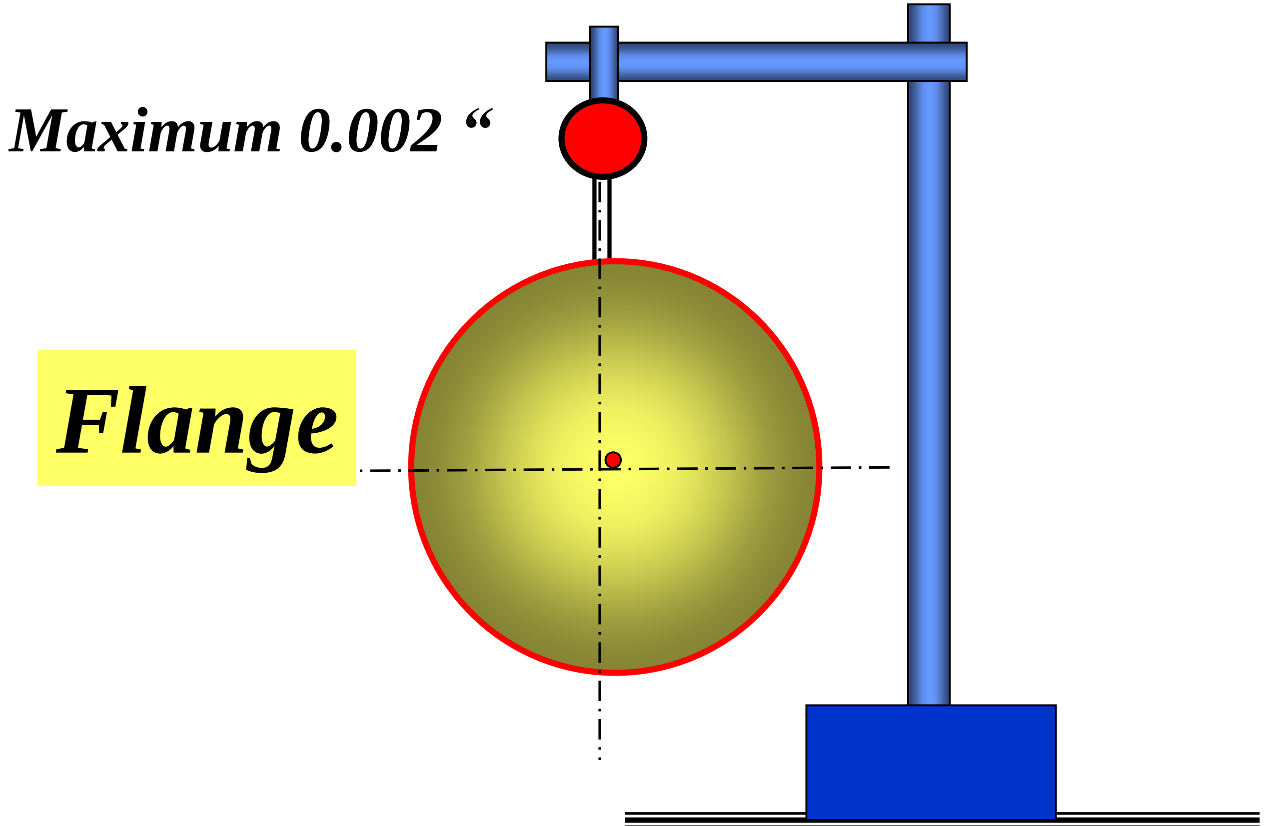
One driver leg is not settled on the base

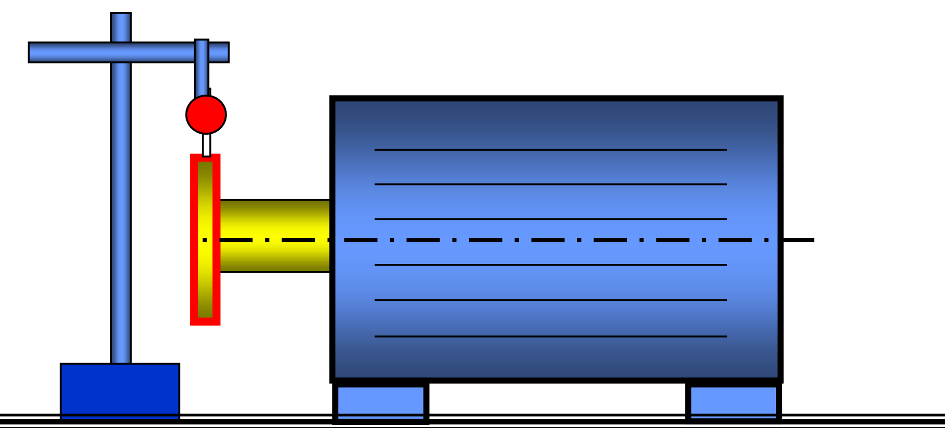


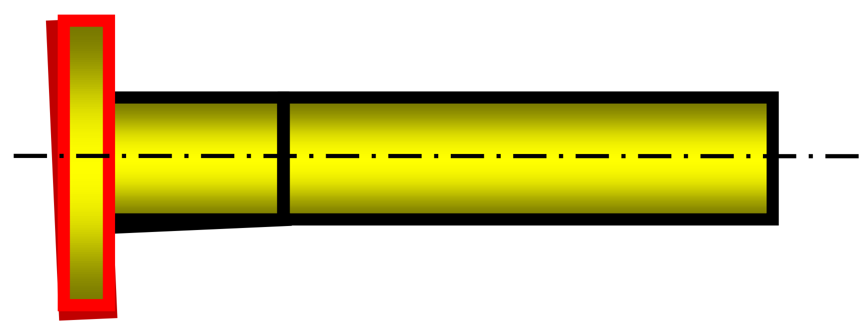
Maximum 0.002 "

* Run out

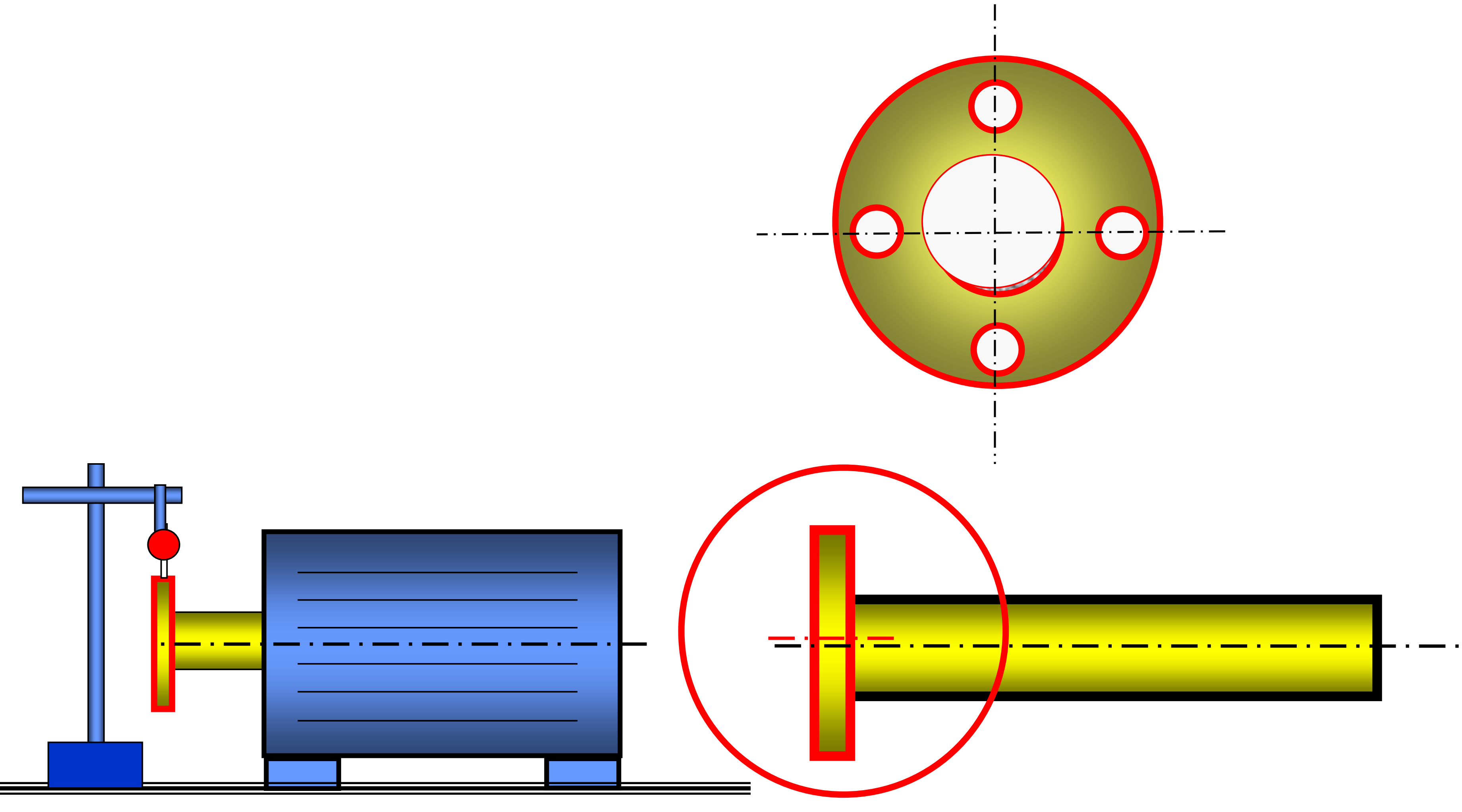
Total Run out



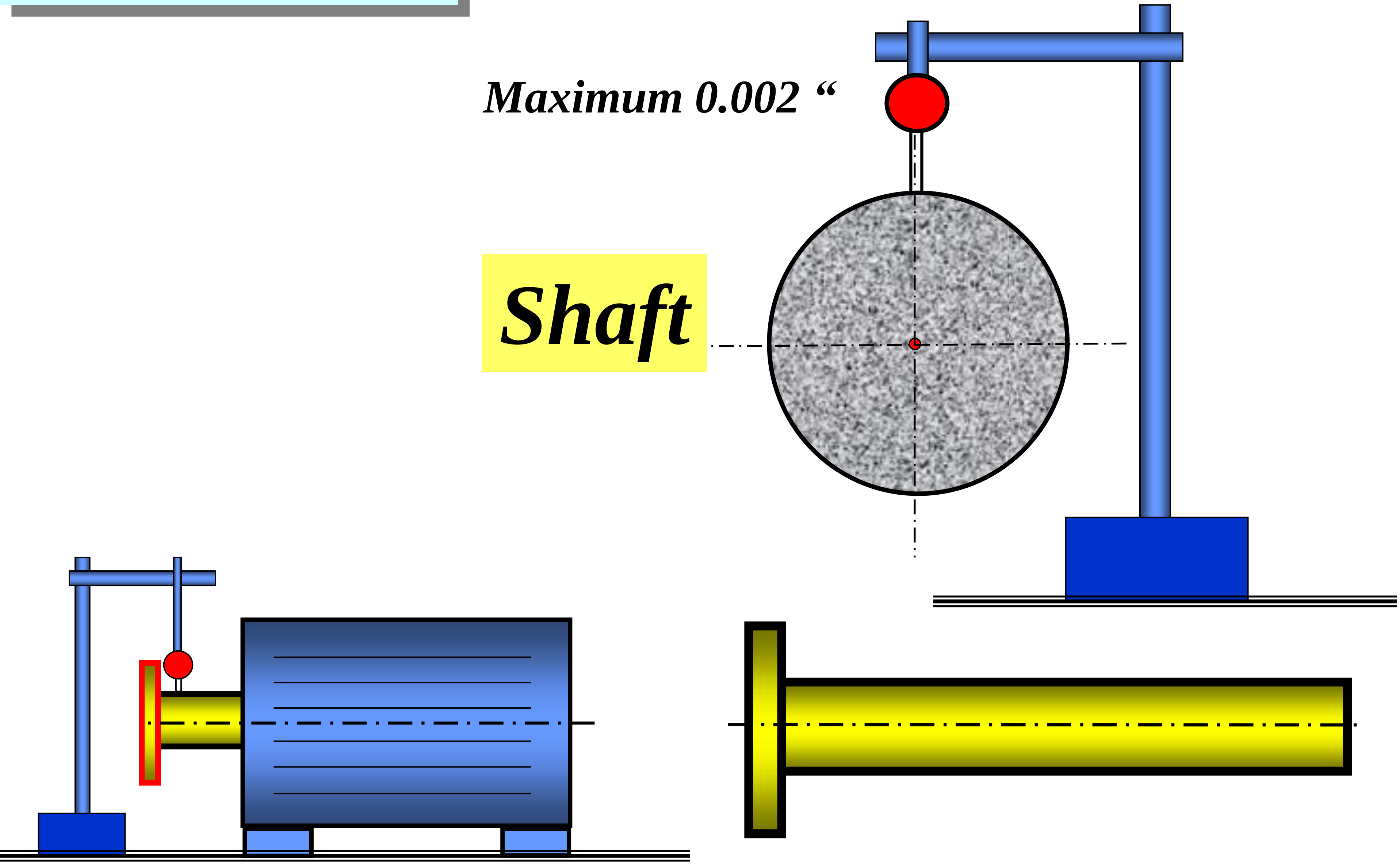




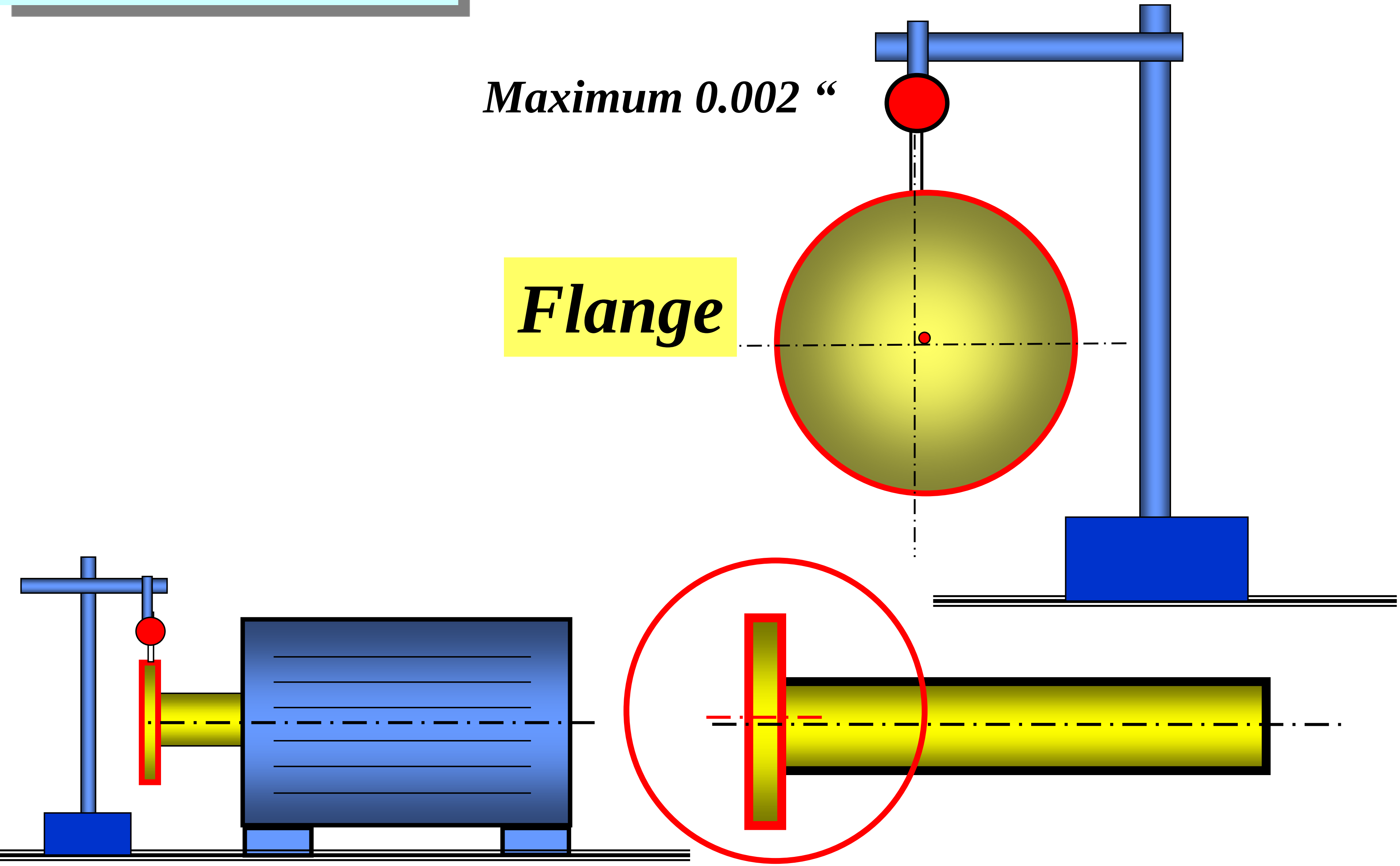
* Run out



* Run out



* Run out



Growth factors (Expansion factor) (mil/in./F) for common materials are as follows:

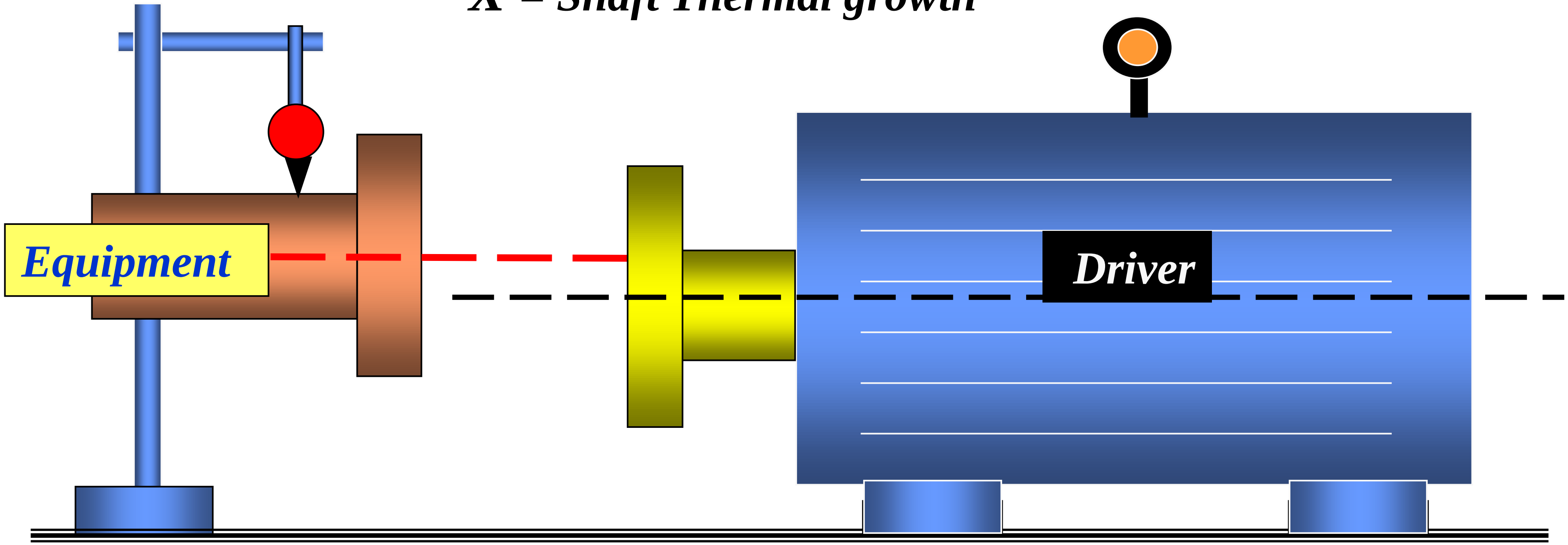
Aluminum	0.0126
Bronze	0.0100
Cast iron, gray	0.0059
Stainless steel	0.0074
Mild steel, ductile iron	0.0063

- For vertical growth, L is usually taken as the vertical height from the bottom of the foot where shims touch the machine to the shaft centerline.
- In the case where the machine is mounted on a base that has significant temperature variations along its length, L is the vertical distance from the concrete or other constant temperature base line to the shaft centerline.

* Thermal growth for hot liquid pumps

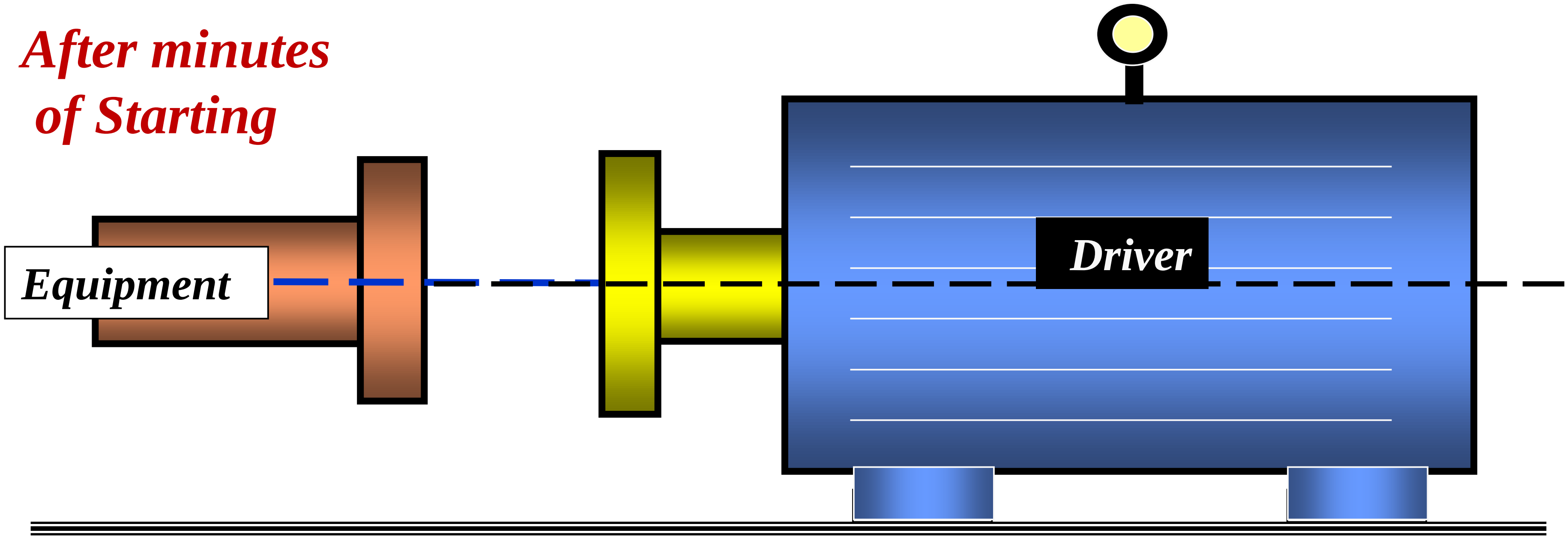
1- Apply the alignment procedure for the pump at ambient Temp.
2- Heat up the pump by opening the start up bypass for ½ hrs.
3- Put the dial indicator on the shaft and adjust to zero reading
4- close the bypass
5- Take the dial indicator reading after 24 hrs.
6- This reading is the shaft thermal growth thermal growth
7- Add the center line thermal growth reading under the driver legs

X = Shaft Thermal growth



* Thermal growth for Compressors

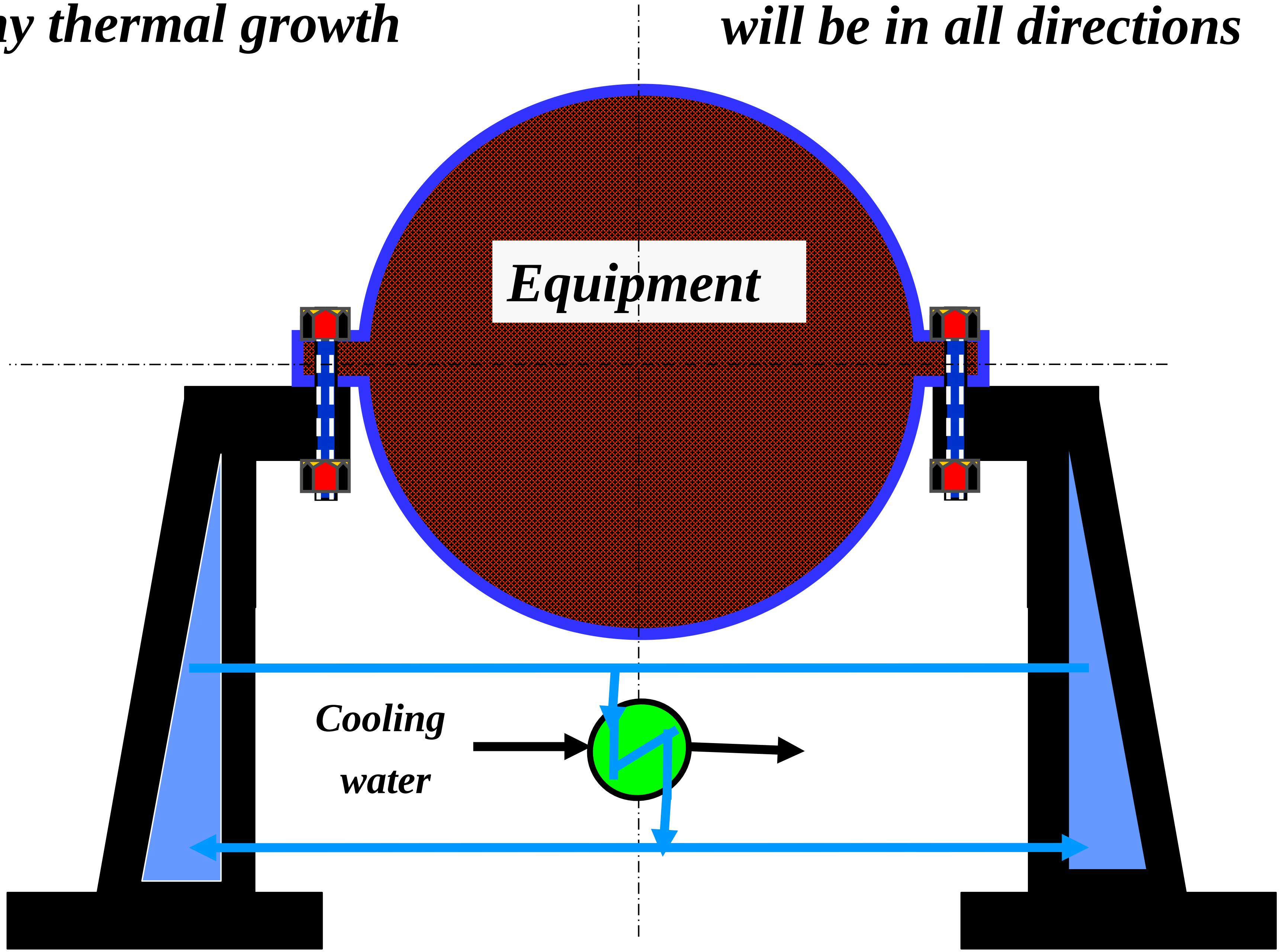
1- Apply the alignment procedure for the compressor at ambient Temp.
2- Go to catalogue and read the center line thermal growth amount.
3- Add the center line thermal growth reading under the driver legs
4- If the equipment manual gives the whole equipment thermal growth
The center line thermal growth = whole equipment thermal growth /2
(Ask the vendor to confirm type of catalogue thermal growth)



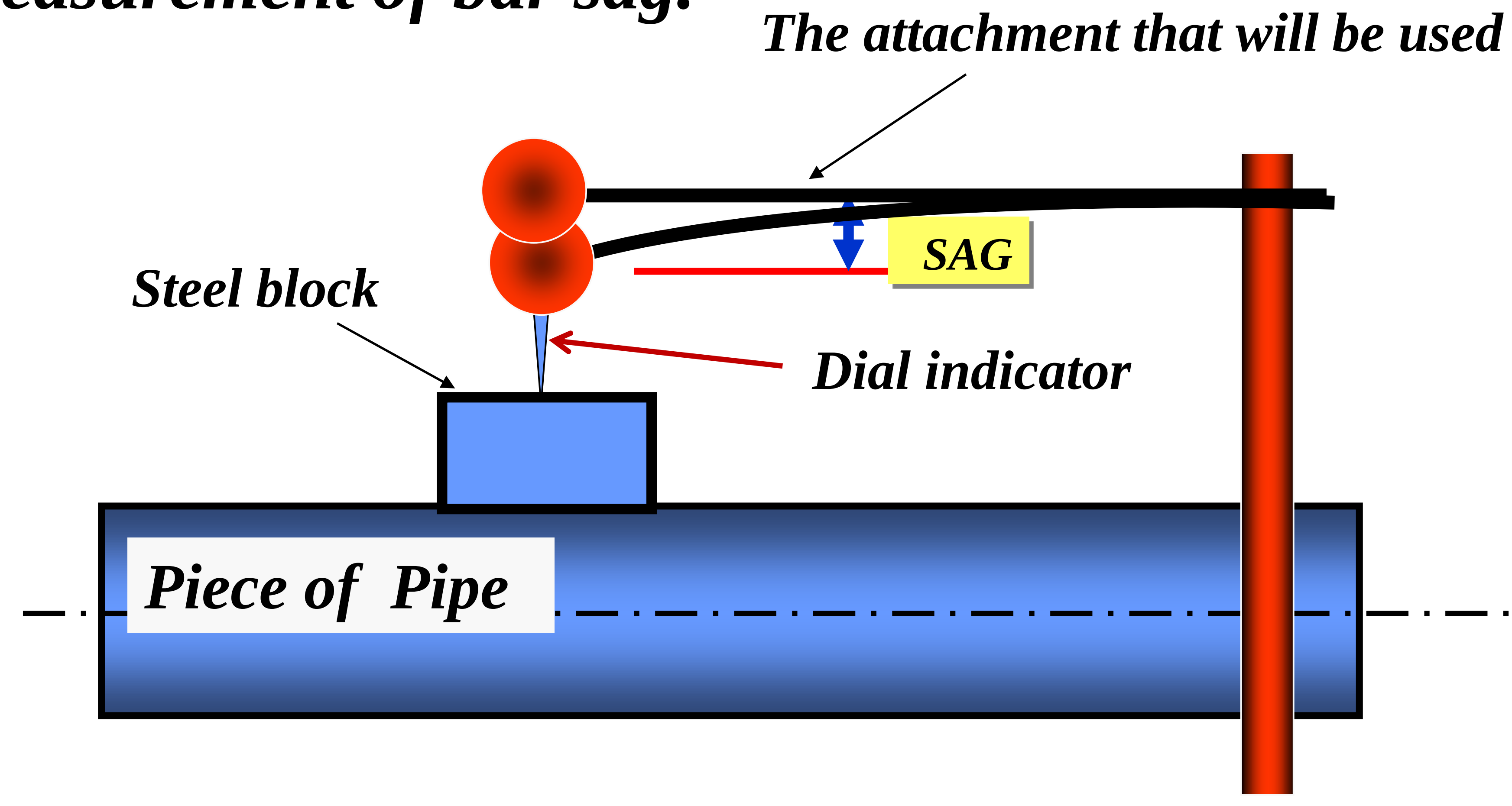
X = The center line Thermal growth

This design is to avoid any thermal growth

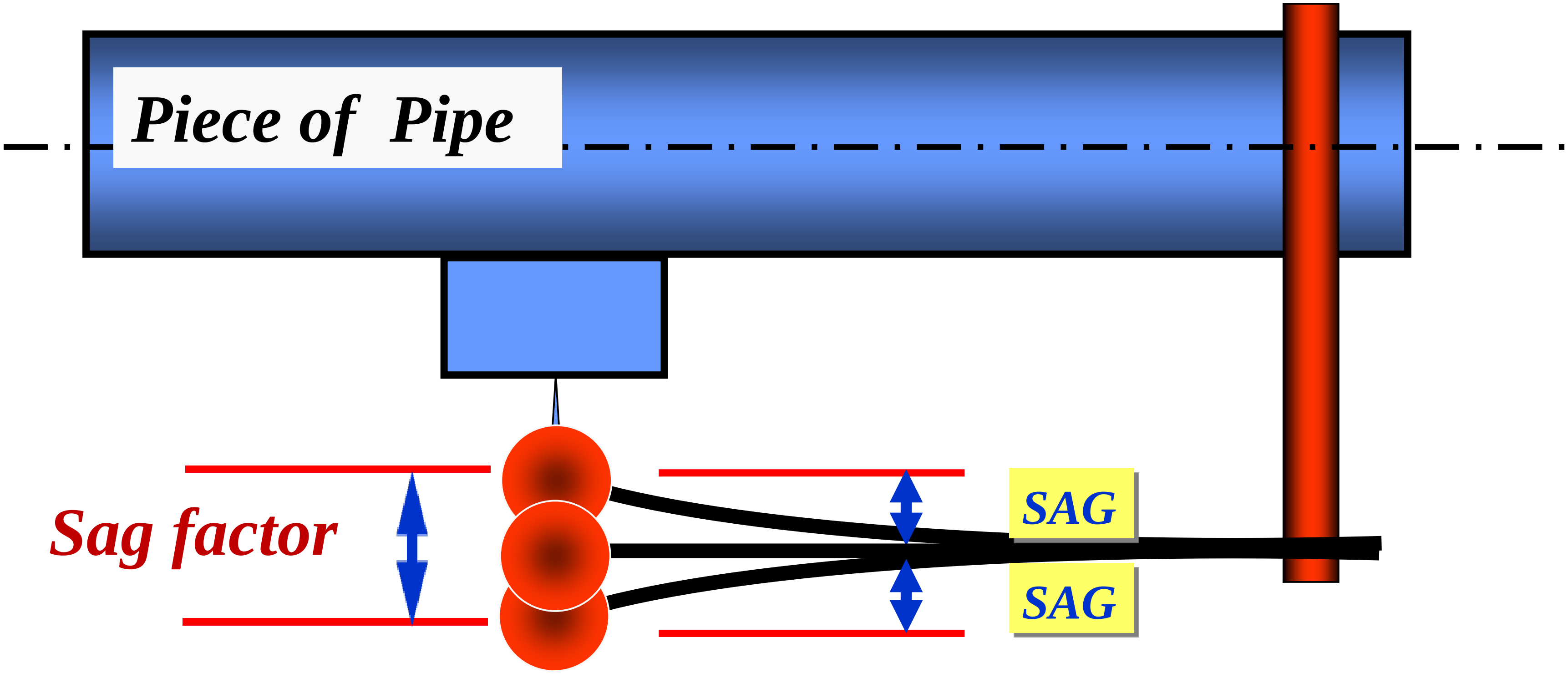
As thermal expansion will be in all directions



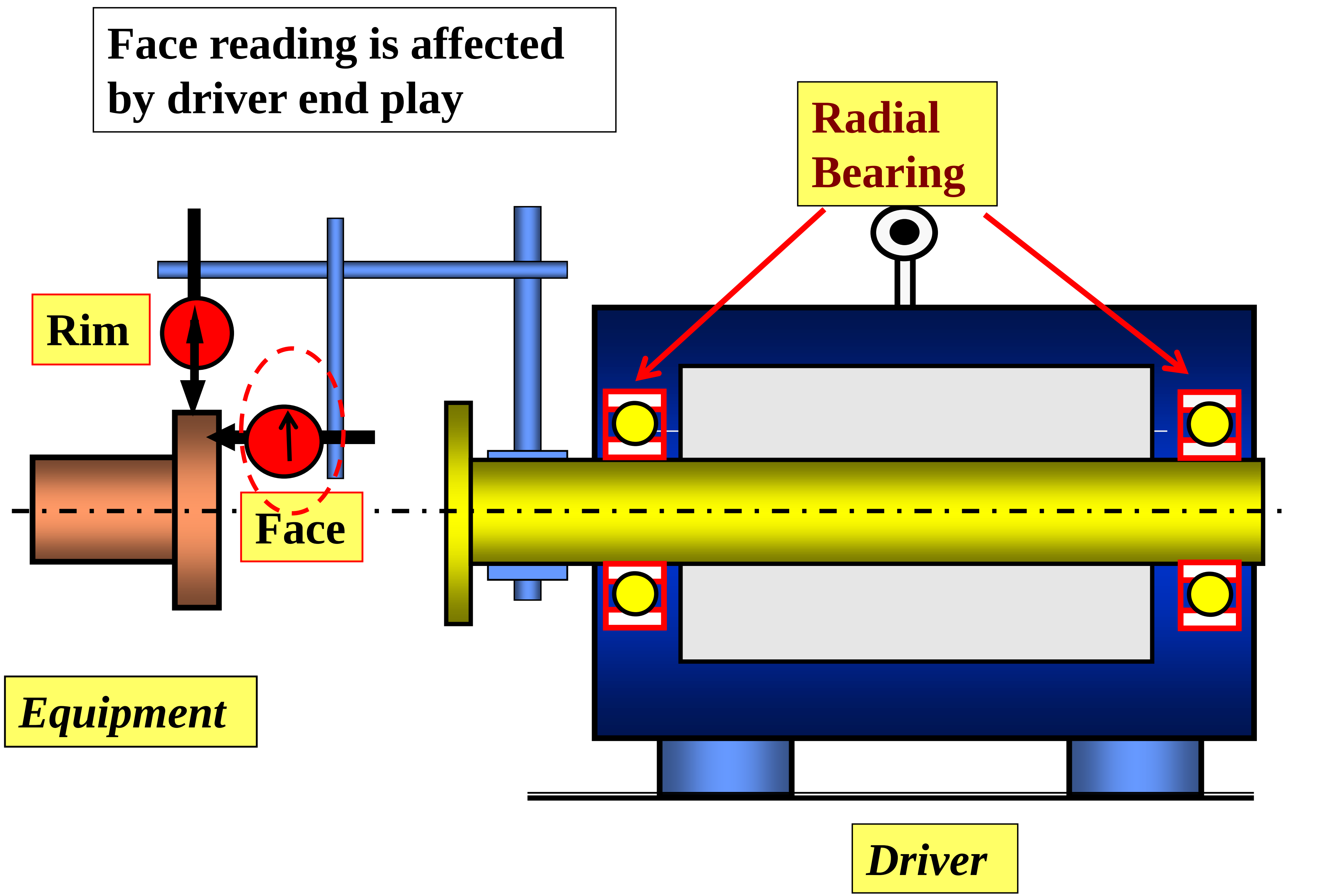
Measurement of bar sag.



Bar Sag on 12 O'clock Position


Piece of Pipe
Sag factor
SAG
SAG

Electrical motors have no thrust bearings

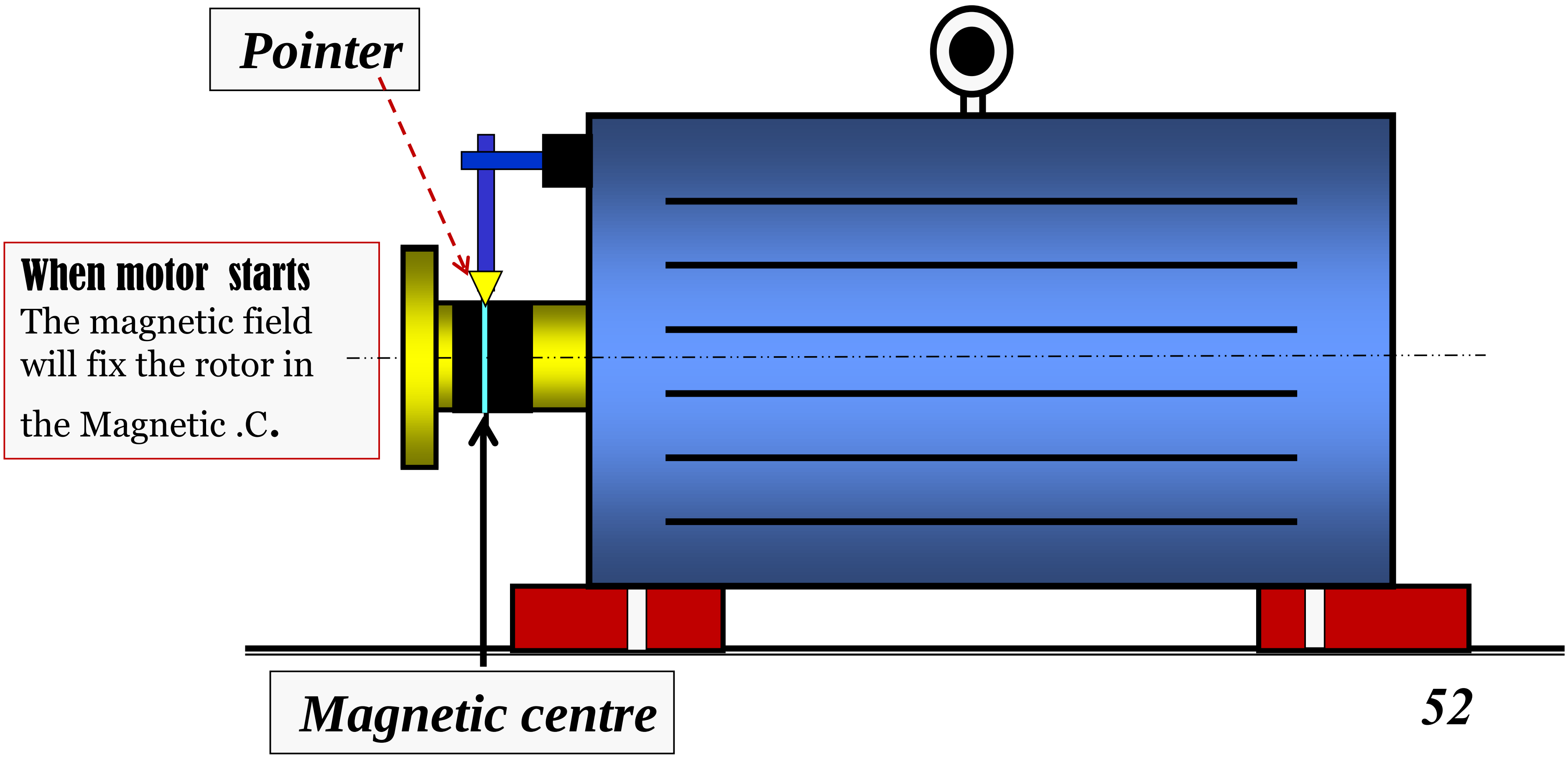


Question :

Why Electrical motors have no thrust bearings

Answer:

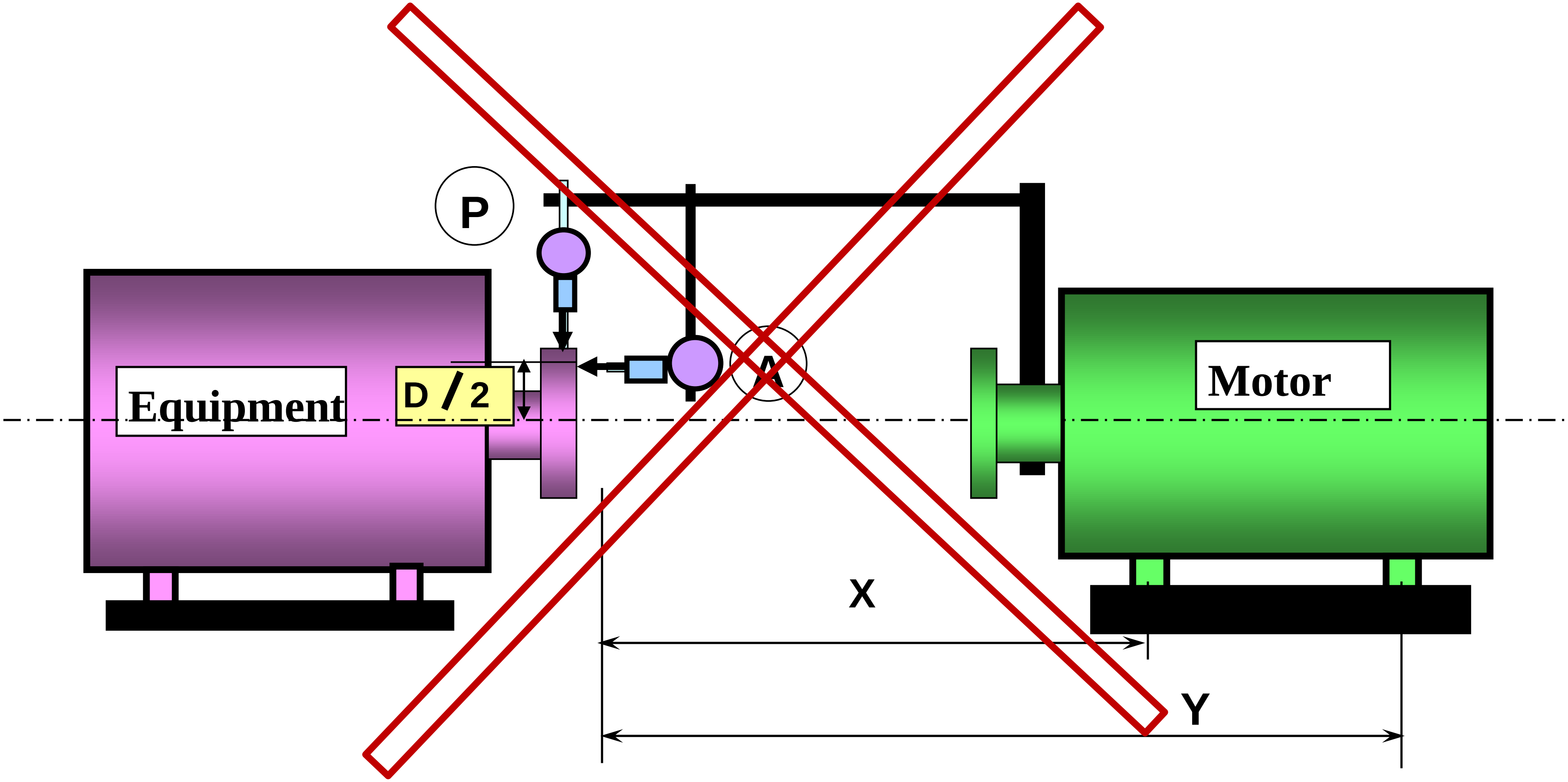
They have instead a magnetic center



Rim and Face

- The face reading error is not sensible during rotating the motor rotor 180 deg. to measure the misalignment reading.
- We don't know the rotor travel distance, is inward or outward ???
- Reversal alignment has Zero error and is the basic of the optical alignment

Rim and Face



~~**Rim and Face Alignment**~~

is prohibited all over the world because of the rotor axial movement affects the dial indicator face reading

Use only

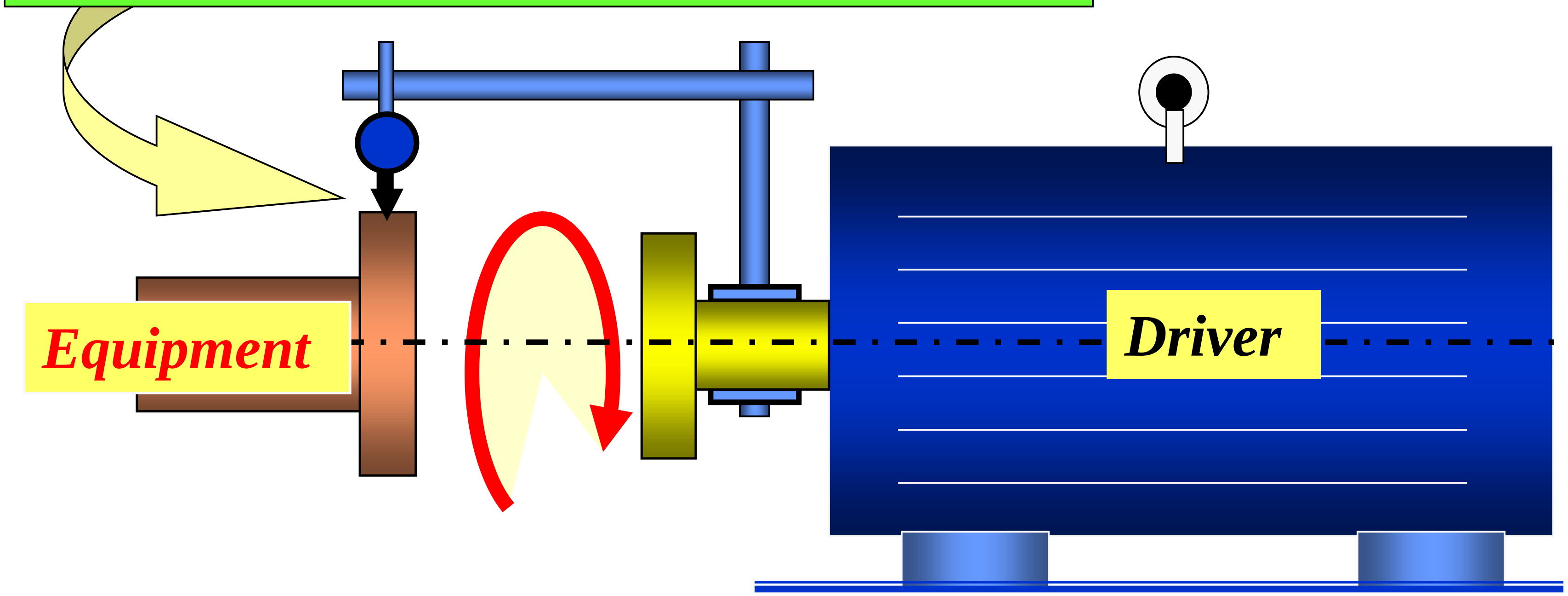
--Reversal Alignment or

--Optical Alignment

How To Do Alignment

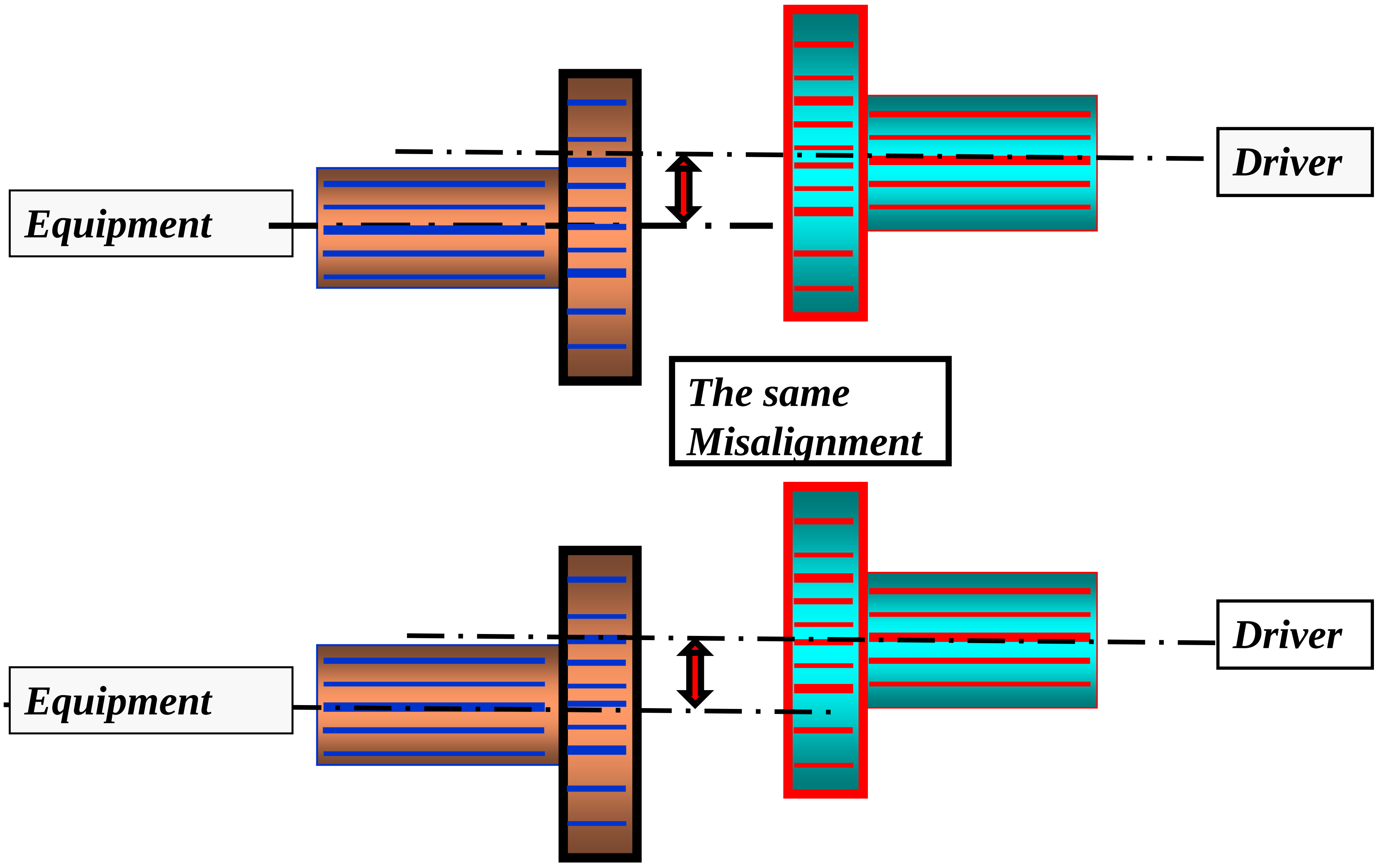
Gauge Pointer

does not move around the rim

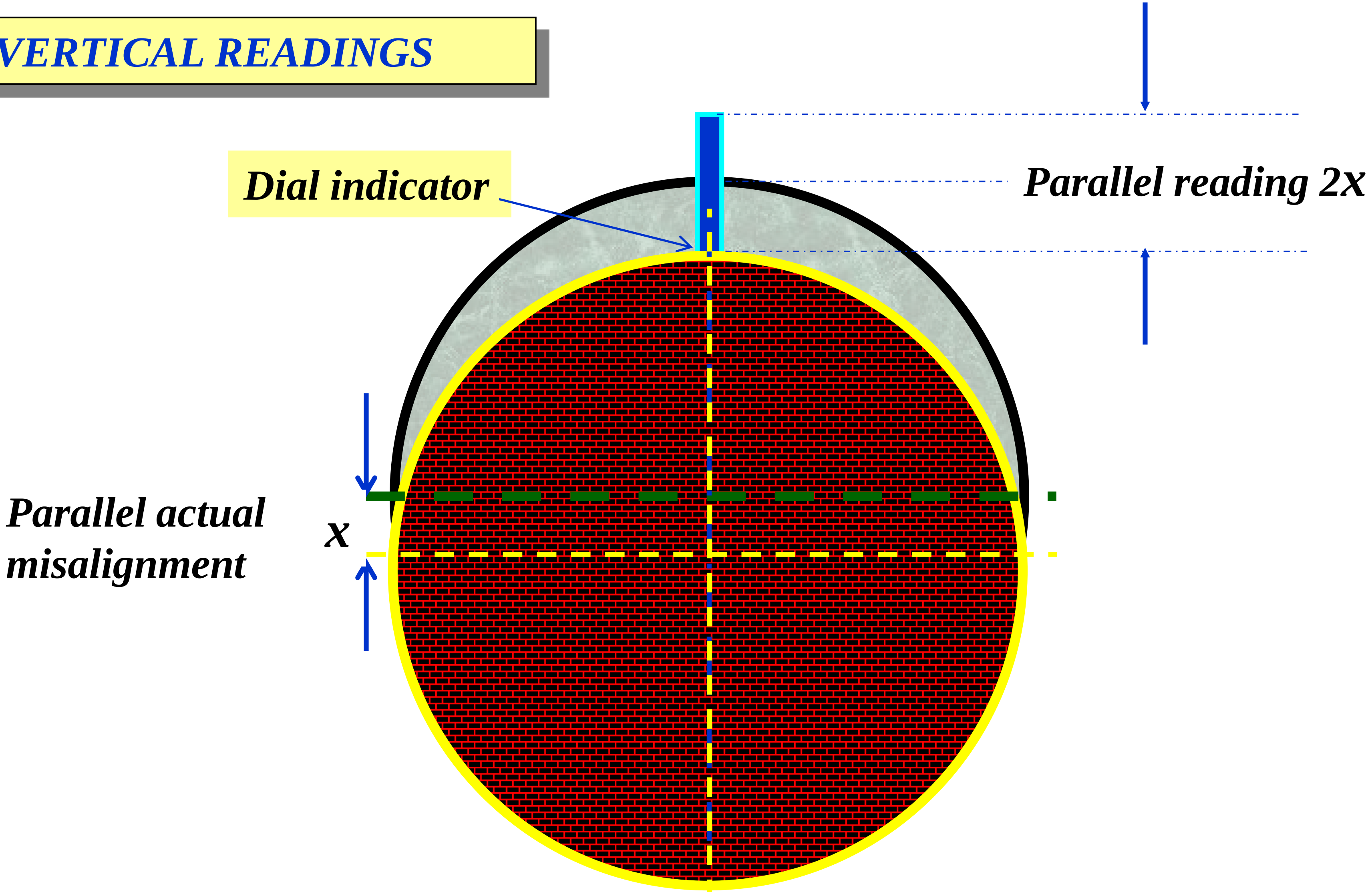


Motor and Equipment shaft

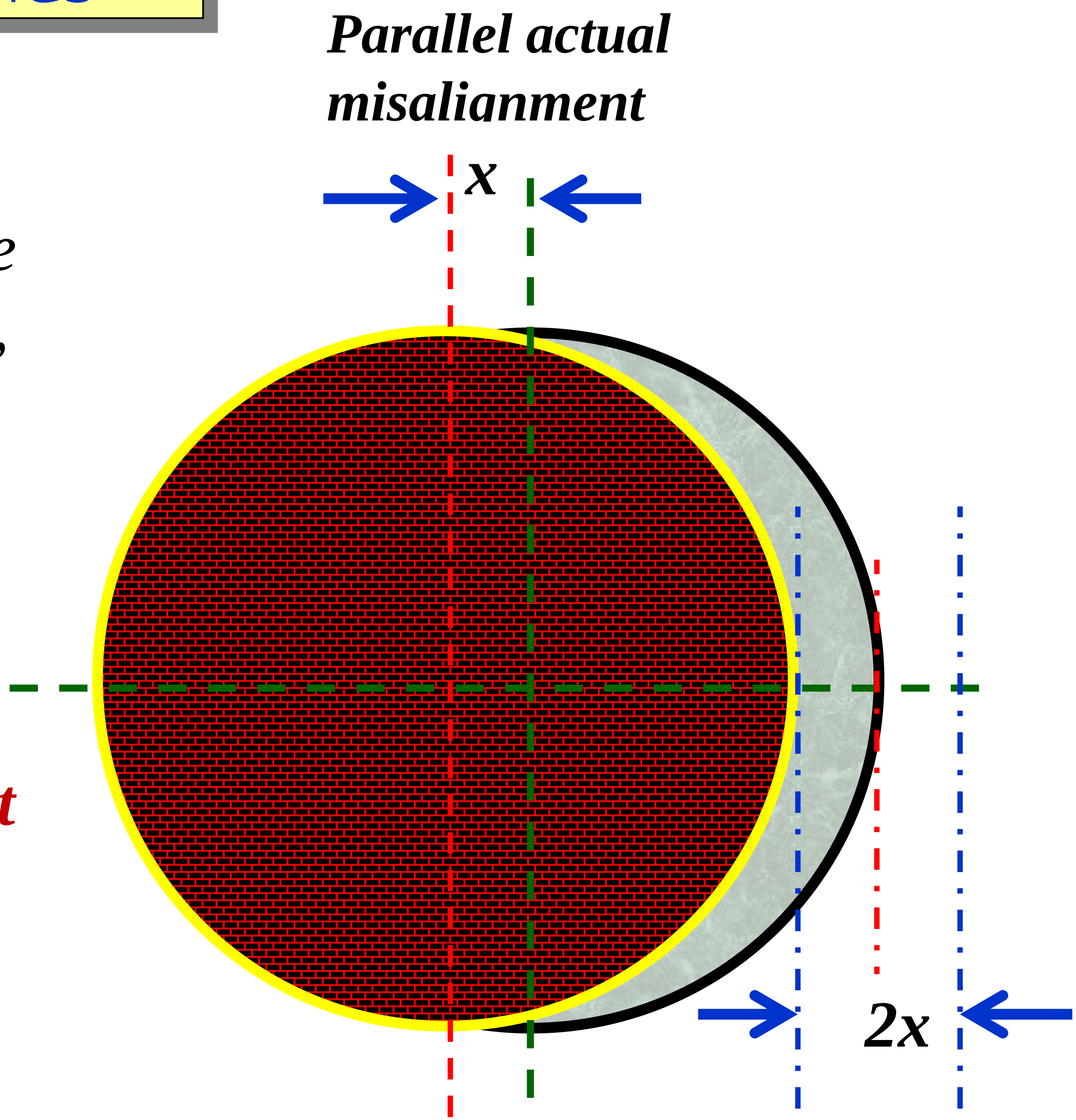
Rotate in the same time


Equipment
Driver
The same Misalignment
Equipment
Driver

VERTICAL READINGS



HORIZONTAL READINGS



If :

- *Both shafts rotate*

Or - *One shaft rotates,*

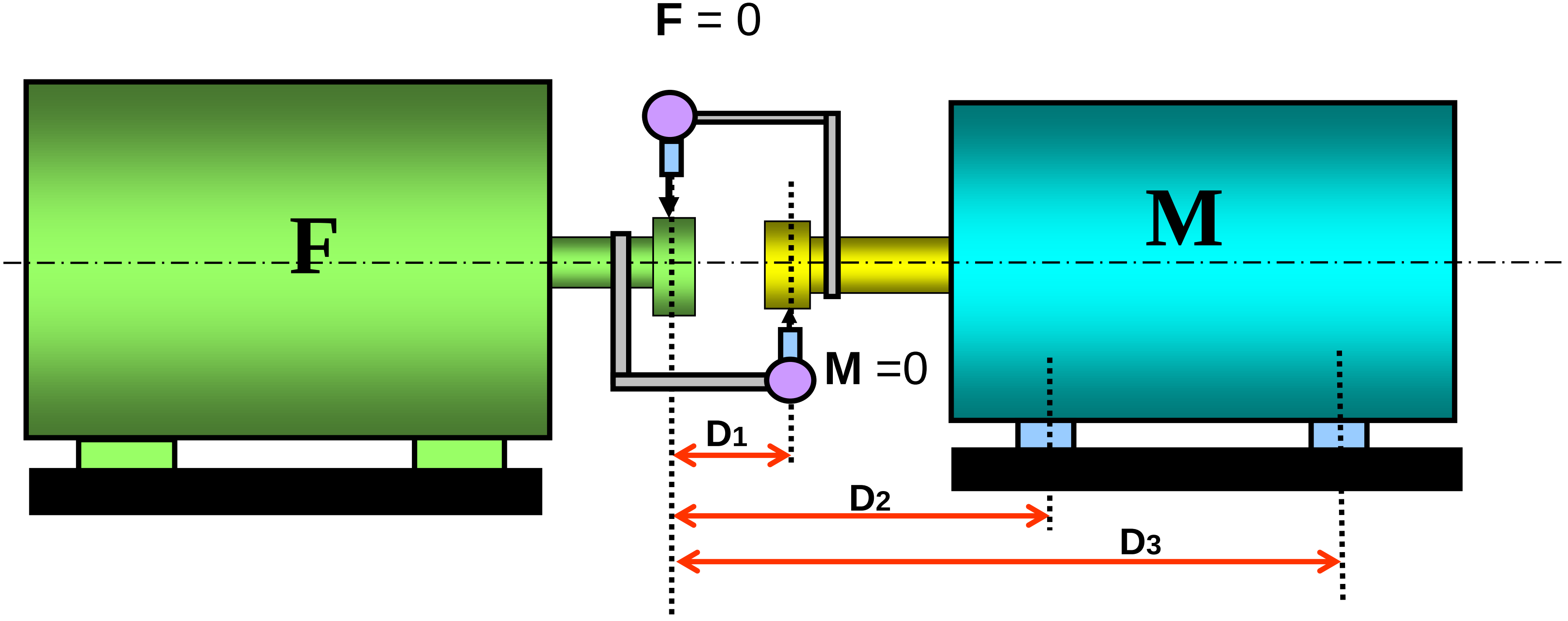
The dial indicator reading is the same,

And equal to:

Double of the actual Misalignment amount

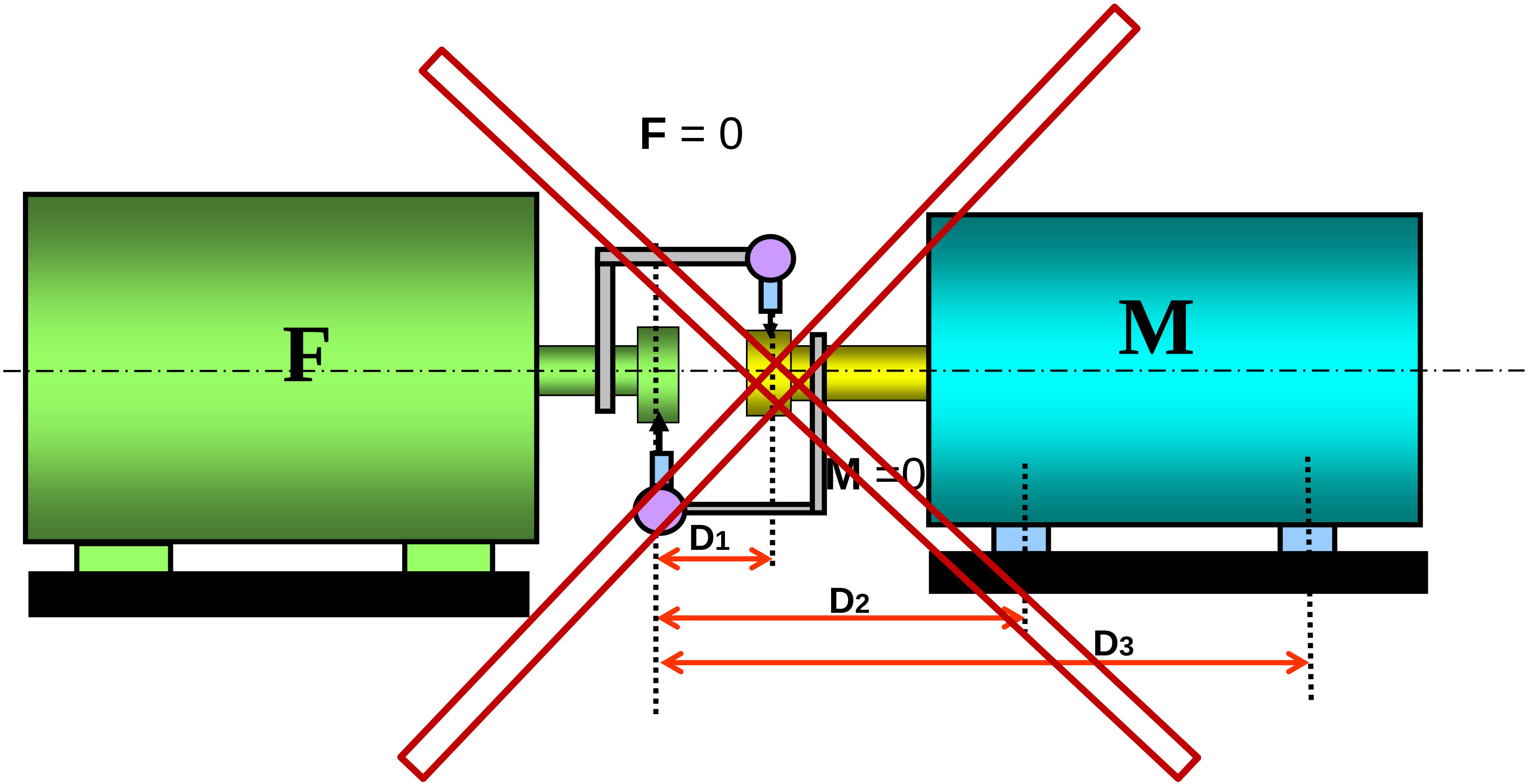
Reversal Alignment

This arrangement is compulsory to start Reversal Alignment

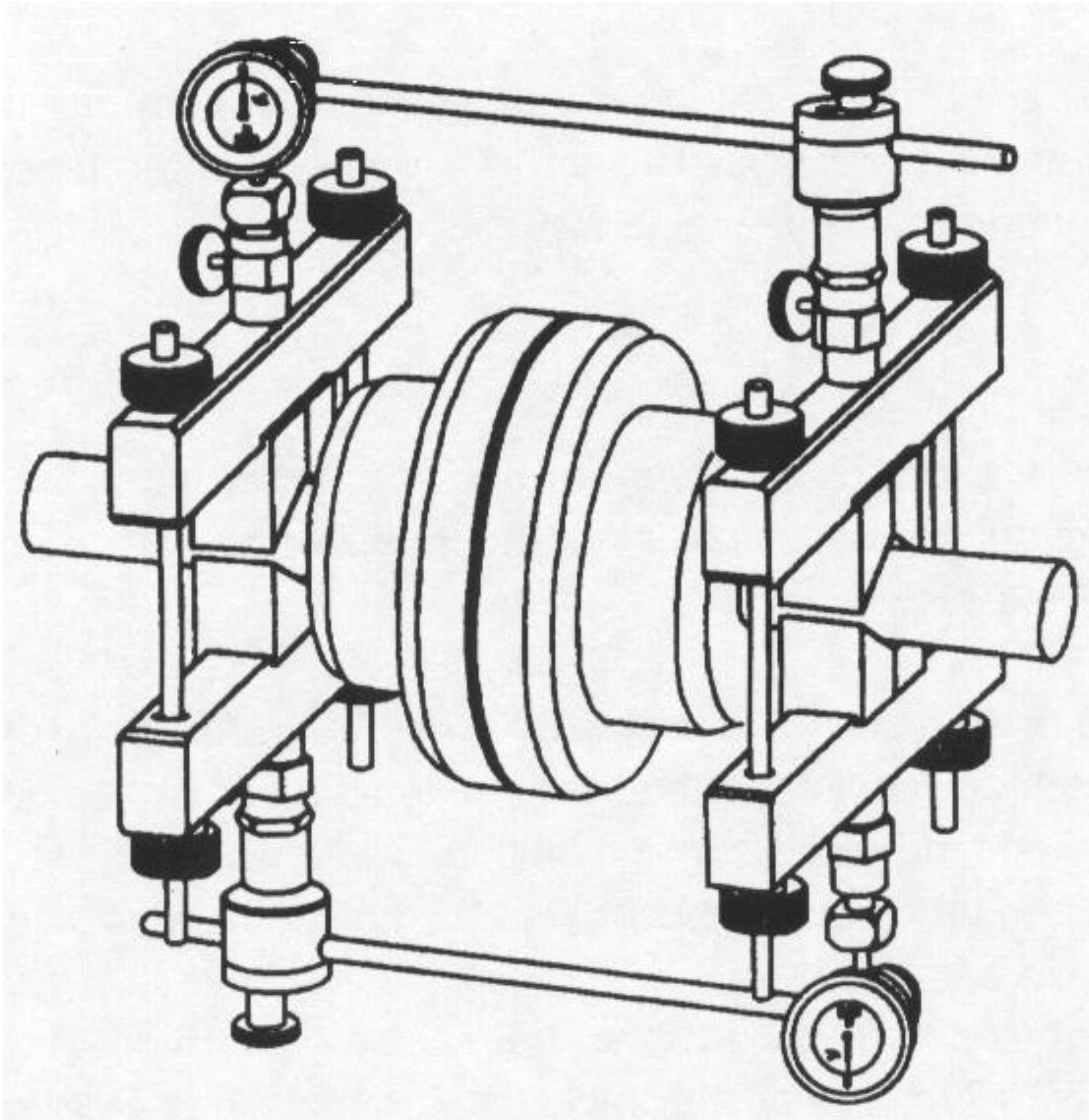


Reversal Alignment

This arrangement is Wrong to start Reversal Alignment



1-Reversal Alignment

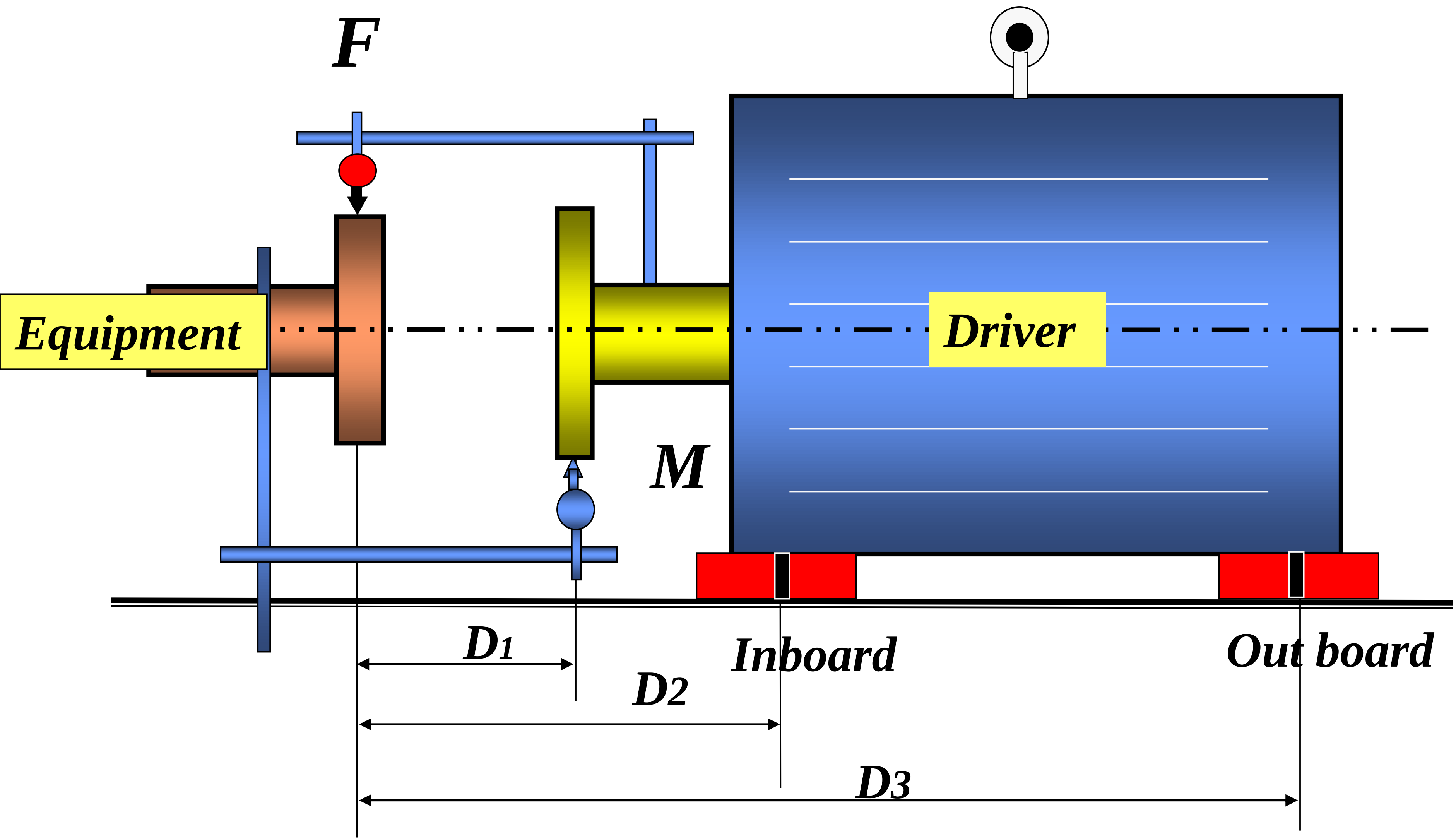


F

M

Reversal Alignment

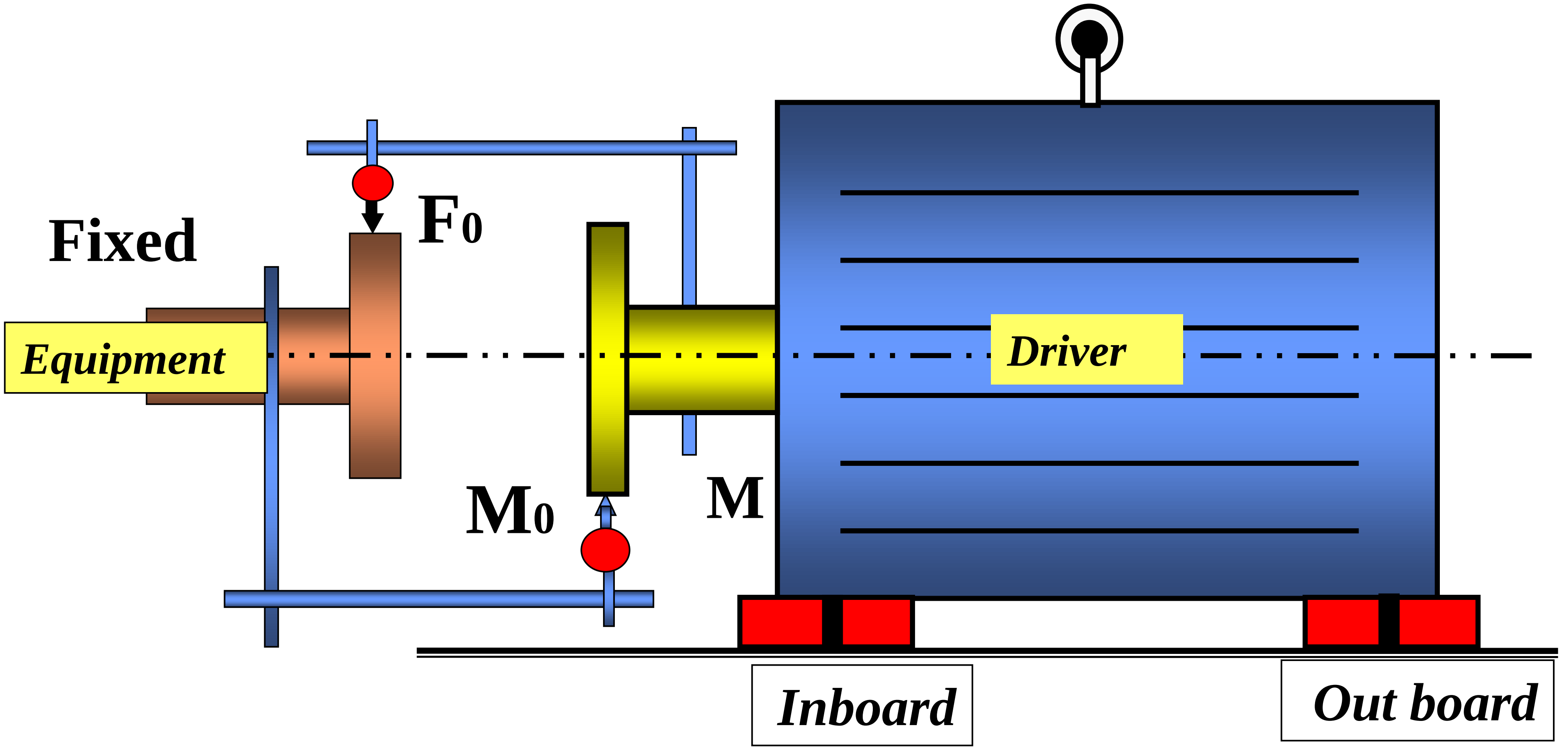
This arrangement is compulsory to start Reversal Alignment



1-Reversal Alignment

F 0 = Zero Reading

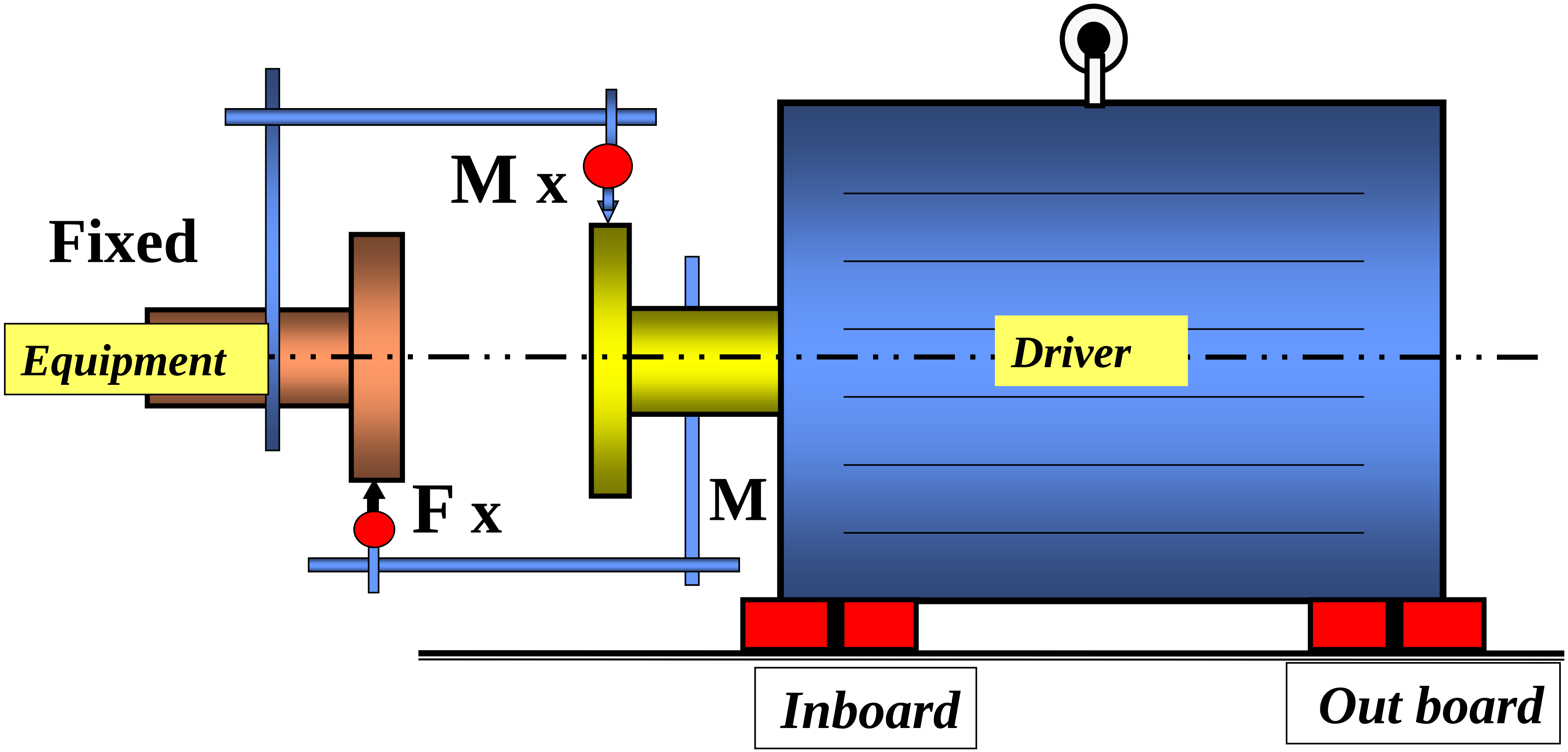
M 0 = Zero Reading

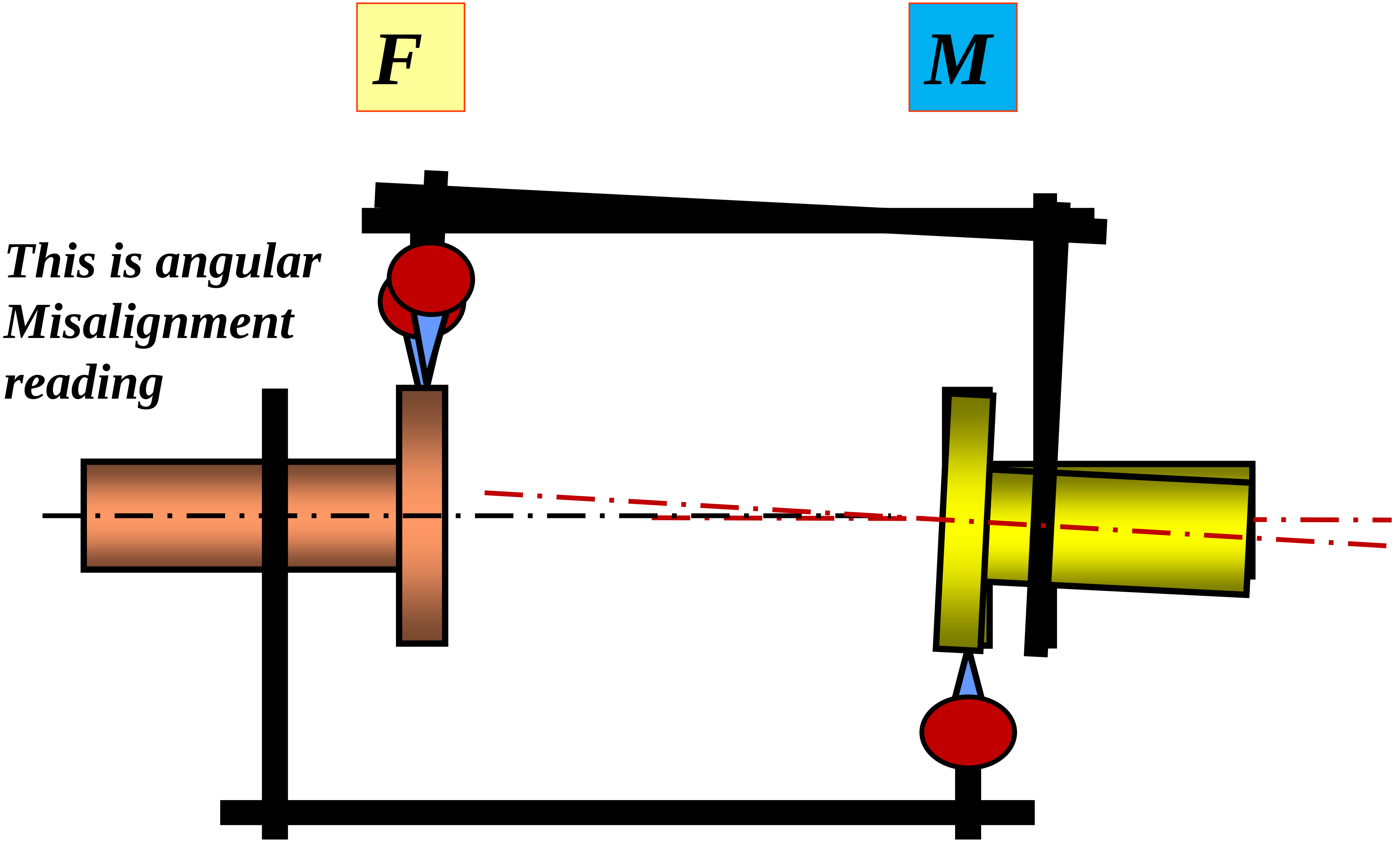


1-Reversal Alignment

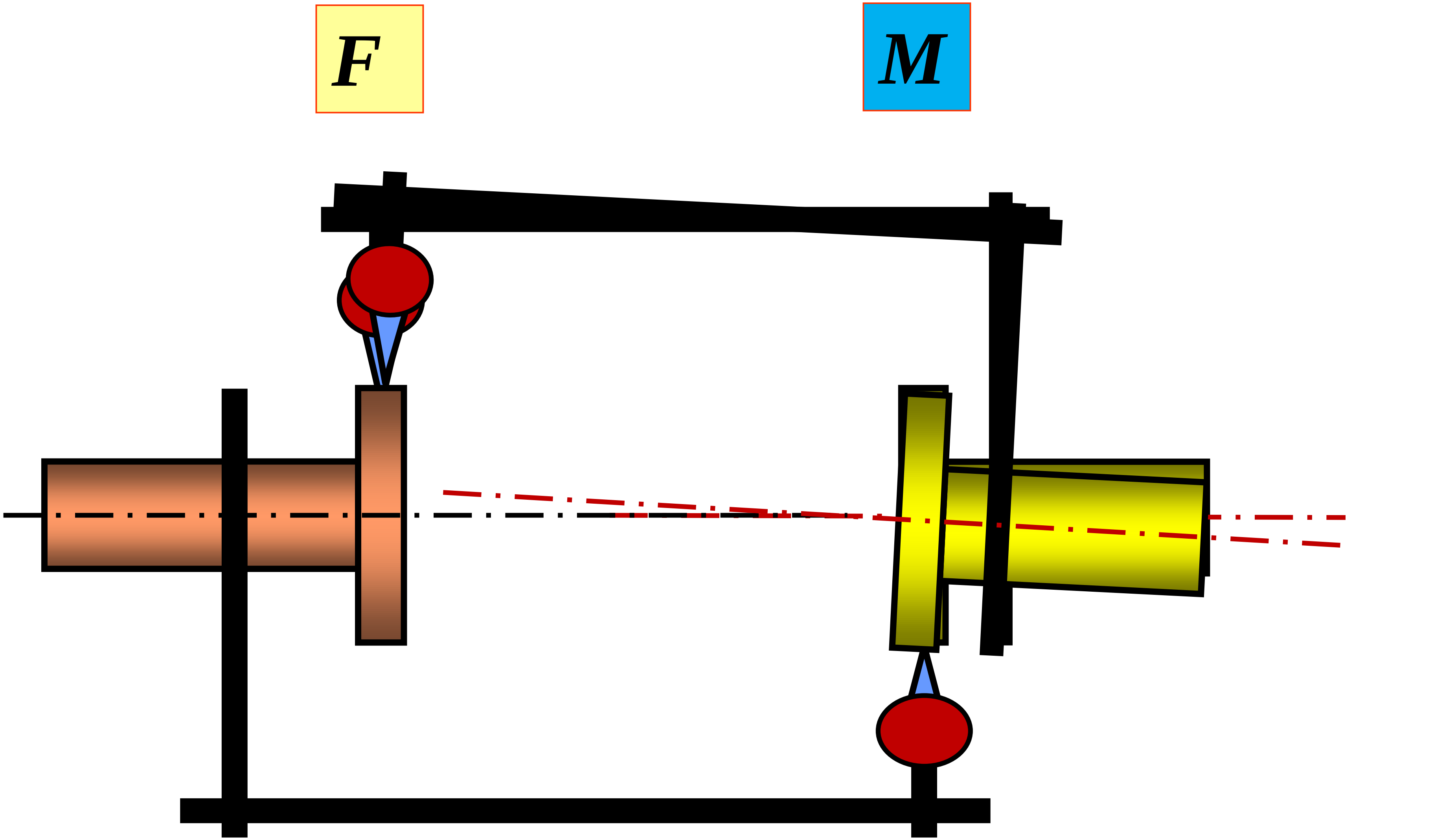
F x = Misalignment Reading

M x = Misalignment Reading

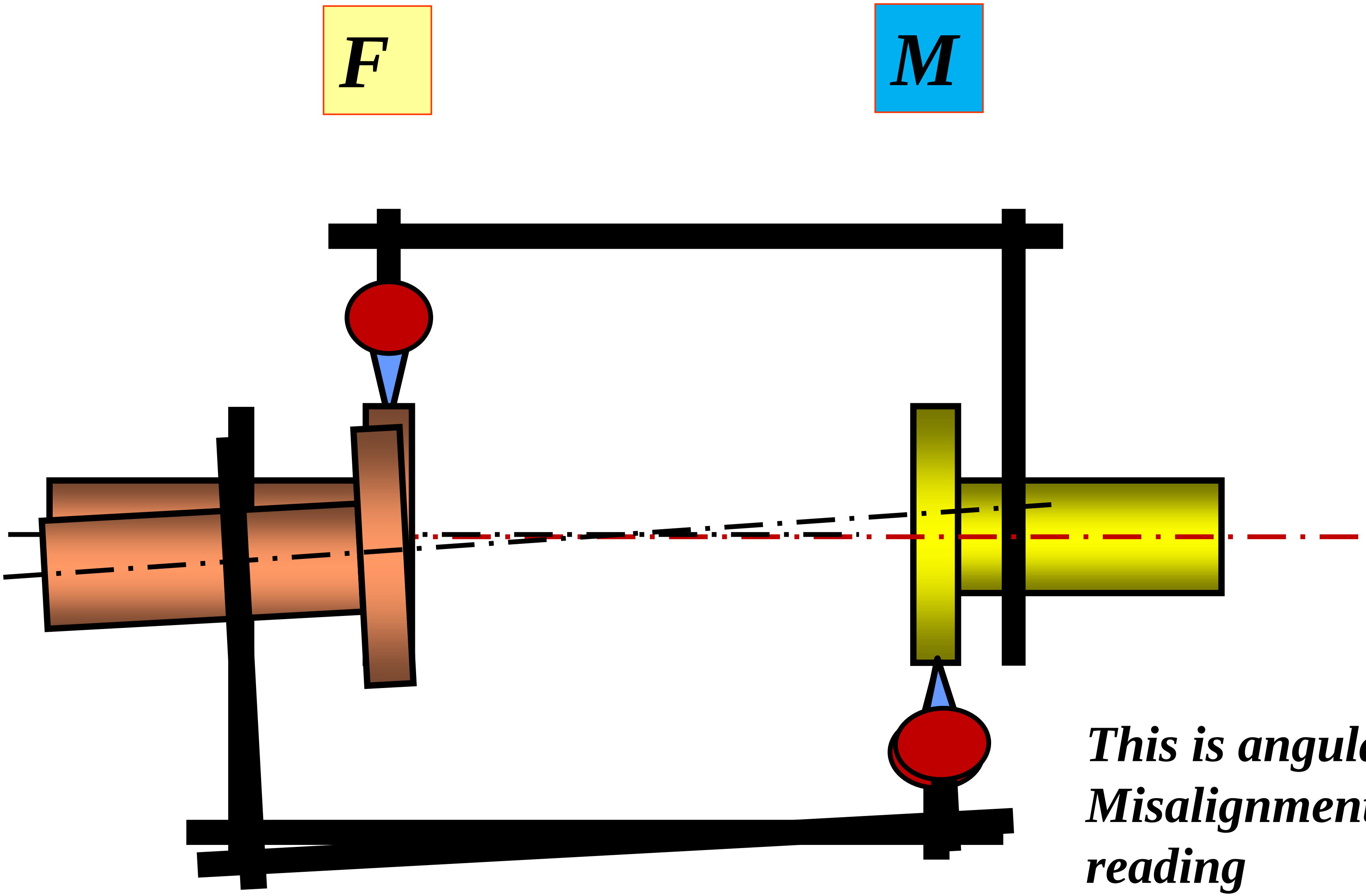




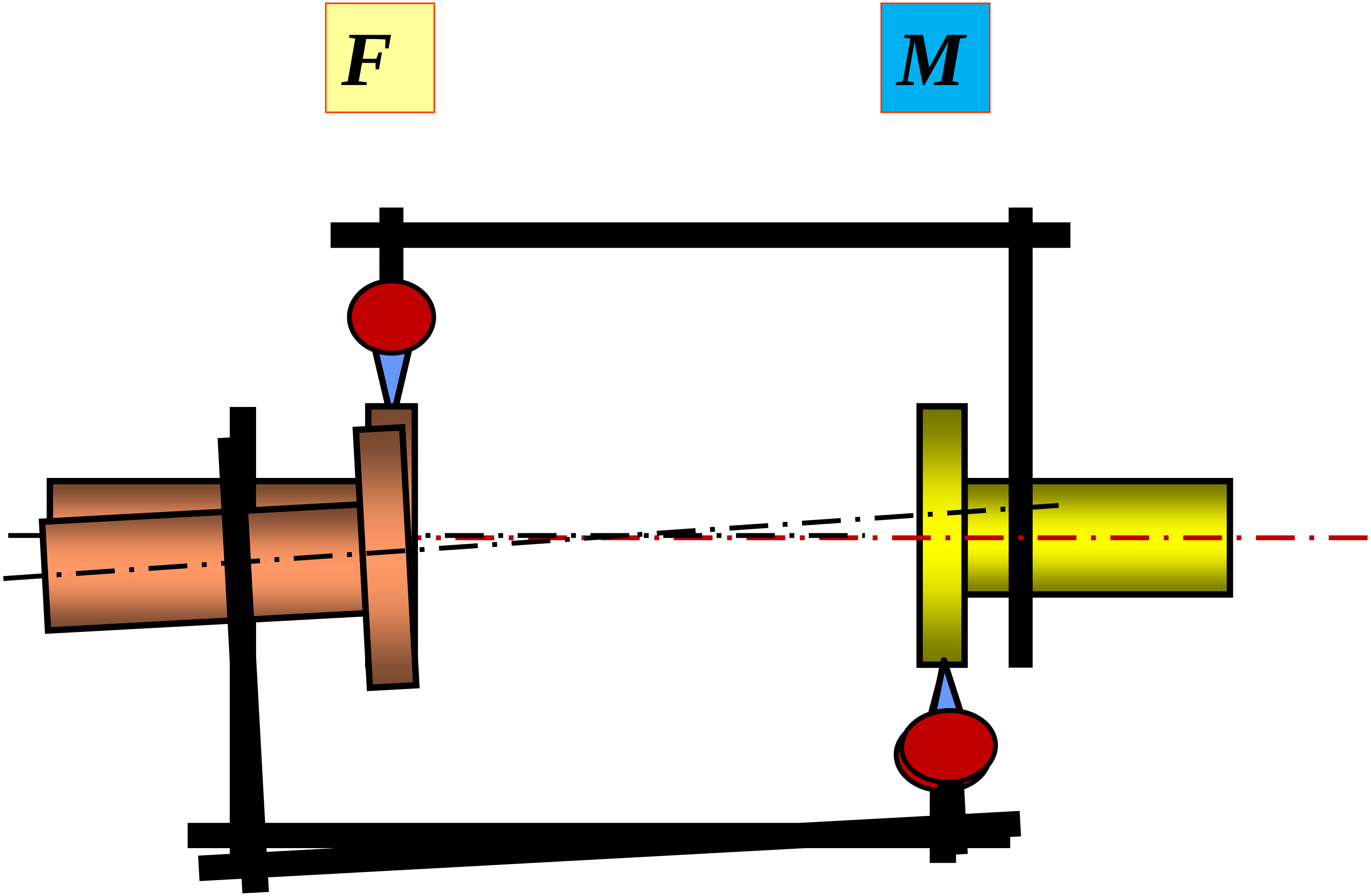
The Reversal alignment method, eliminates the Angular misalignment due to prime mover axial movement



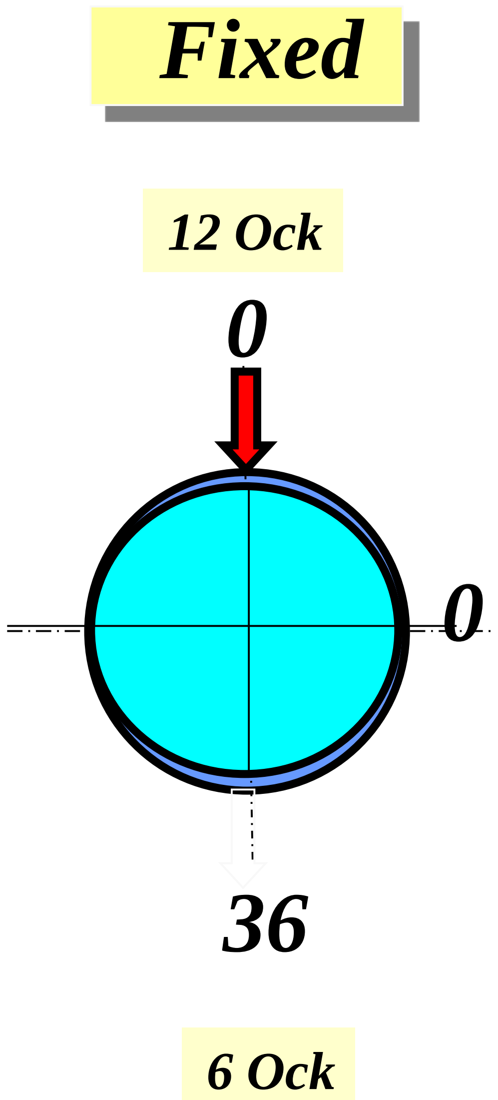
F
M

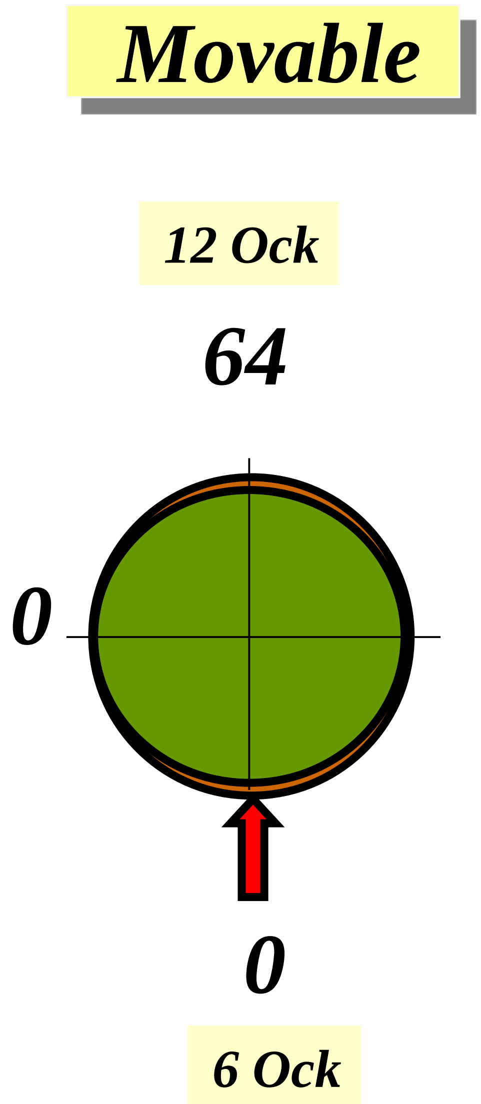


This is angular Misalignment reading

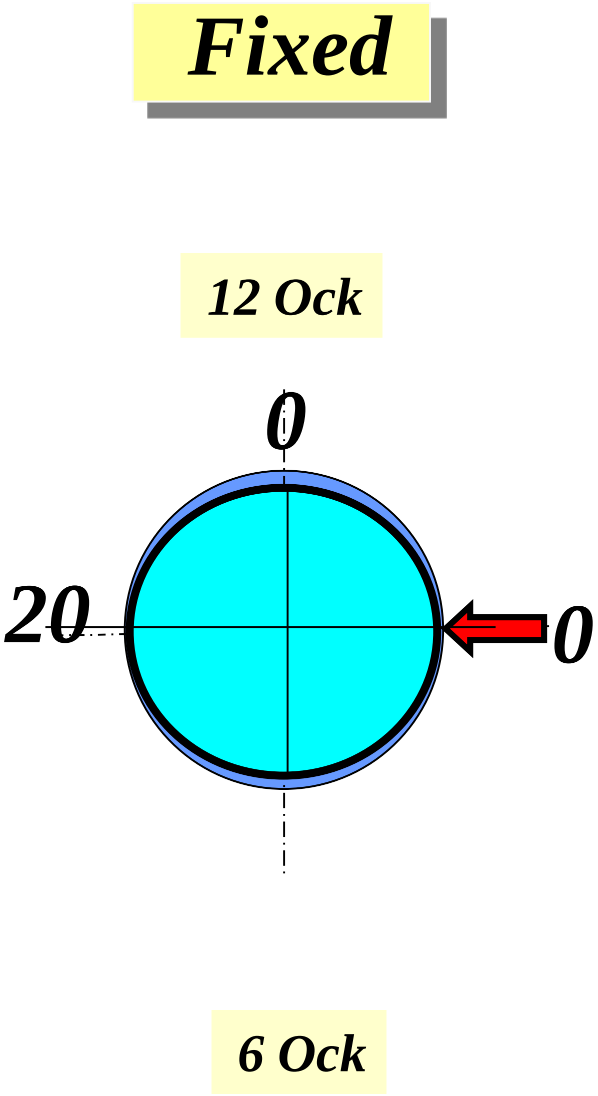

F
M

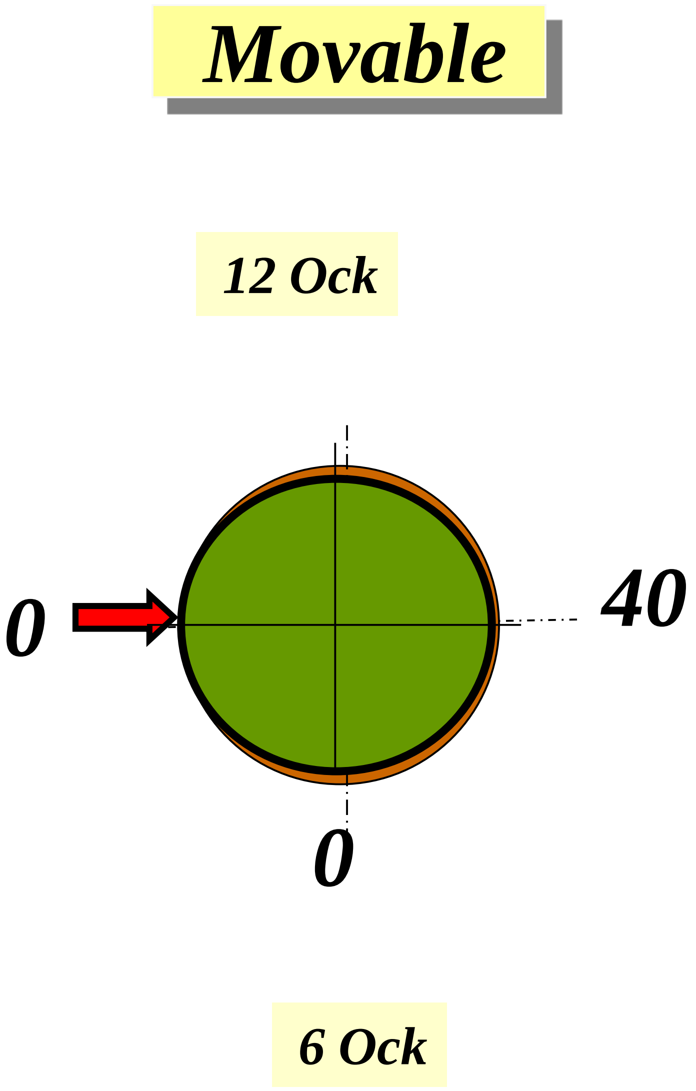
Parallel Reading Vertical





Parallel Reading Horizontal





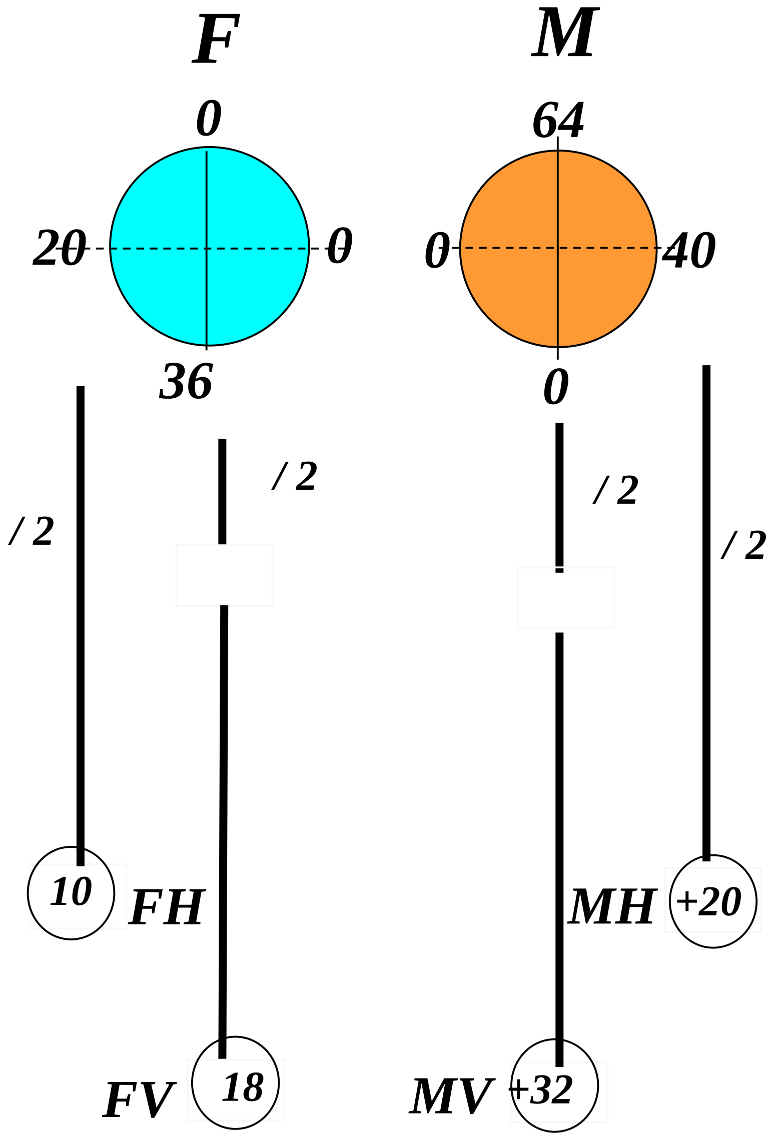
1-Reversal Alignment Calculation Method

D 1 =

D 2 =

D 3 =

Sag = (0)



VERTICALLY

$$\text{INBOARD} = \{ MV - FV \} \frac{D\,2}{D\,1} + FV$$

$$\text{OUTBOARD} = \{ MV - FV \} \frac{D\,3}{D\,1} + FV$$

HORIZONTALLY

$$\text{INBOARD} = \{ MH - FH \} \frac{D\,2}{D\,1} + FH$$

$$\text{OUTBOARD} = \{ MH - FH \} \frac{D\,3}{D\,1} + FH$$

Mils

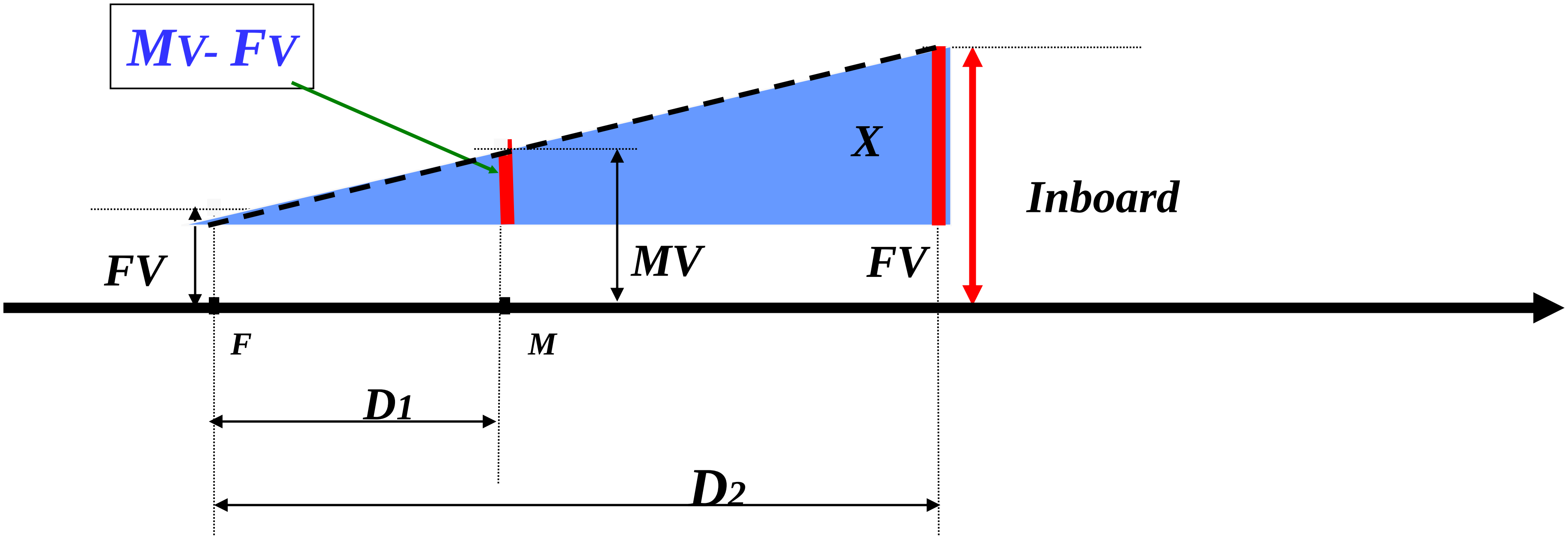
VERTICALLY

$$INBOARD = X + FV$$

$$\frac{X}{M_V - F_V} = \frac{D_2}{D_1}$$

$$INBOARD = \{ M_V - F_V \} \frac{D_2}{D_1} + FV$$

$$X = \{M_V - F_V\} \frac{D_2}{D_1}$$



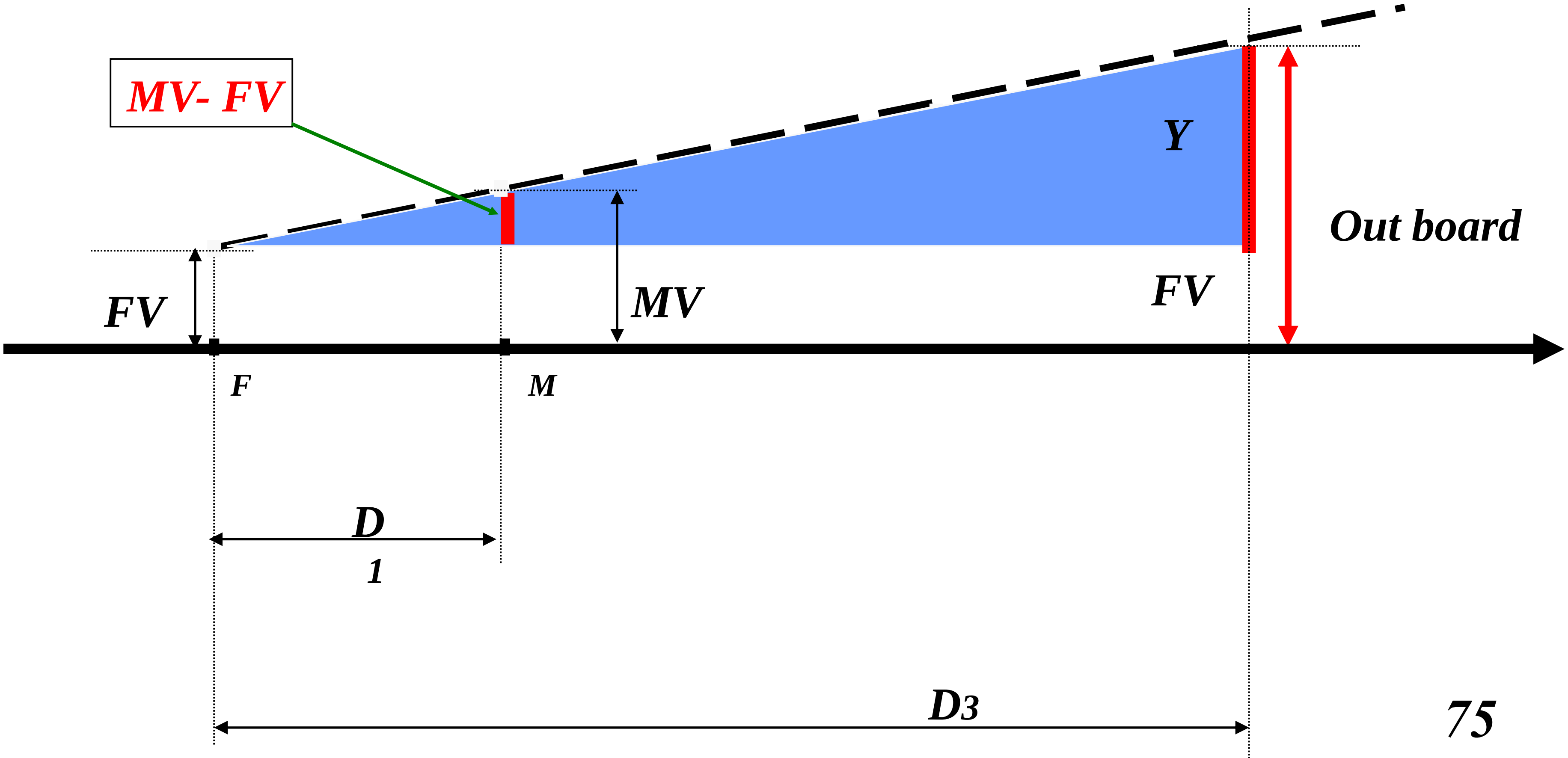
VERTICALLY

$$\text{OUTBOARD} = Y + FV$$

$$\frac{Y}{M_V - F_V} = \frac{D_3}{D_1}$$

$$\text{OUTBOARD} = \{ M_V - F_V \} \frac{D_3}{D_1} + FV$$

$$Y = \{M_V - F_V\} \frac{D_3}{D_1}$$



D1 = 4 in

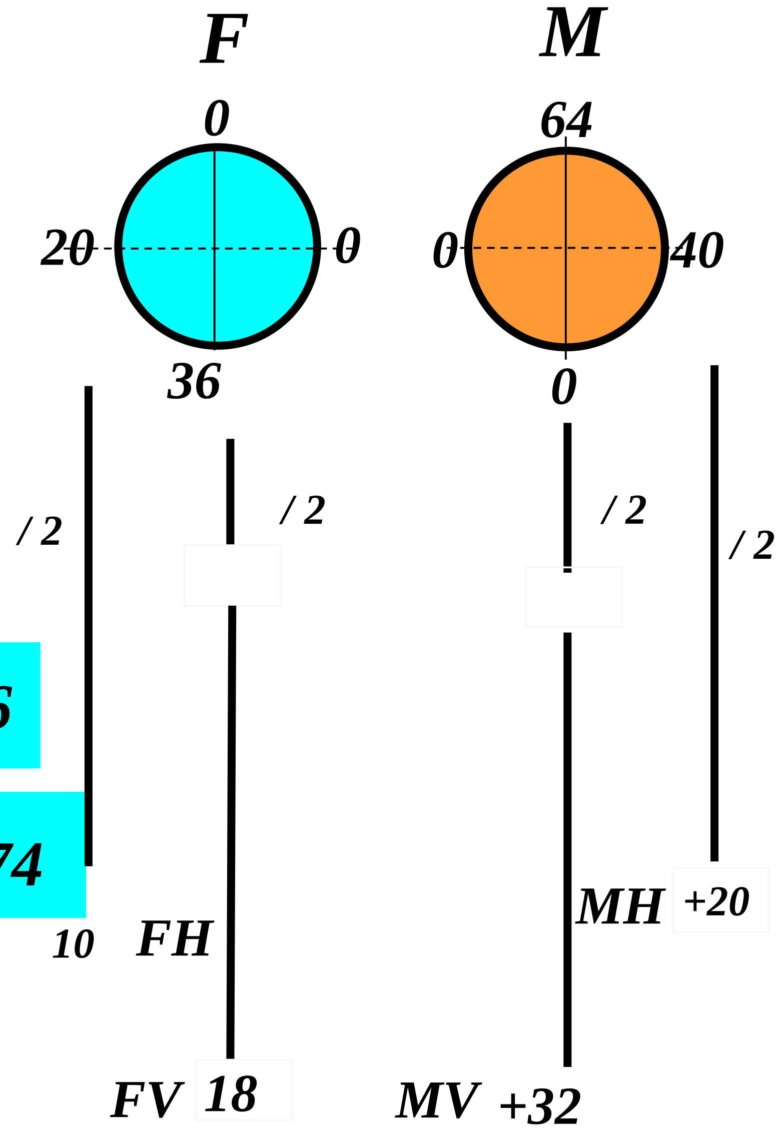
D2 = 8 in

D3 = 16 in

Sag = (0)

F = 0

M = 0



VERTICALLY

$$\text{INBOARD} = \left\{ 32 - 18 \right\} \frac{8}{4} + 18 = +46$$

$$\text{OUTBOARD} = \left\{ 32 - 18 \right\} \frac{16}{4} + 18 = +74$$

HORIZONTALLY

$$\text{INBOARD} = \left\{ 20 - 10 \right\} \frac{8}{4} + 10 = +30$$

$$\text{OUTBOARD} = \left\{ 20 - 10 \right\} \frac{16}{4} + 10 = +50$$

Mils

$D1 = 4$ in
$D2 = 8$ in
$D3 = 16$ in
Sag = (1)

$F = + 1$

$M = -1$

VERTICALLY

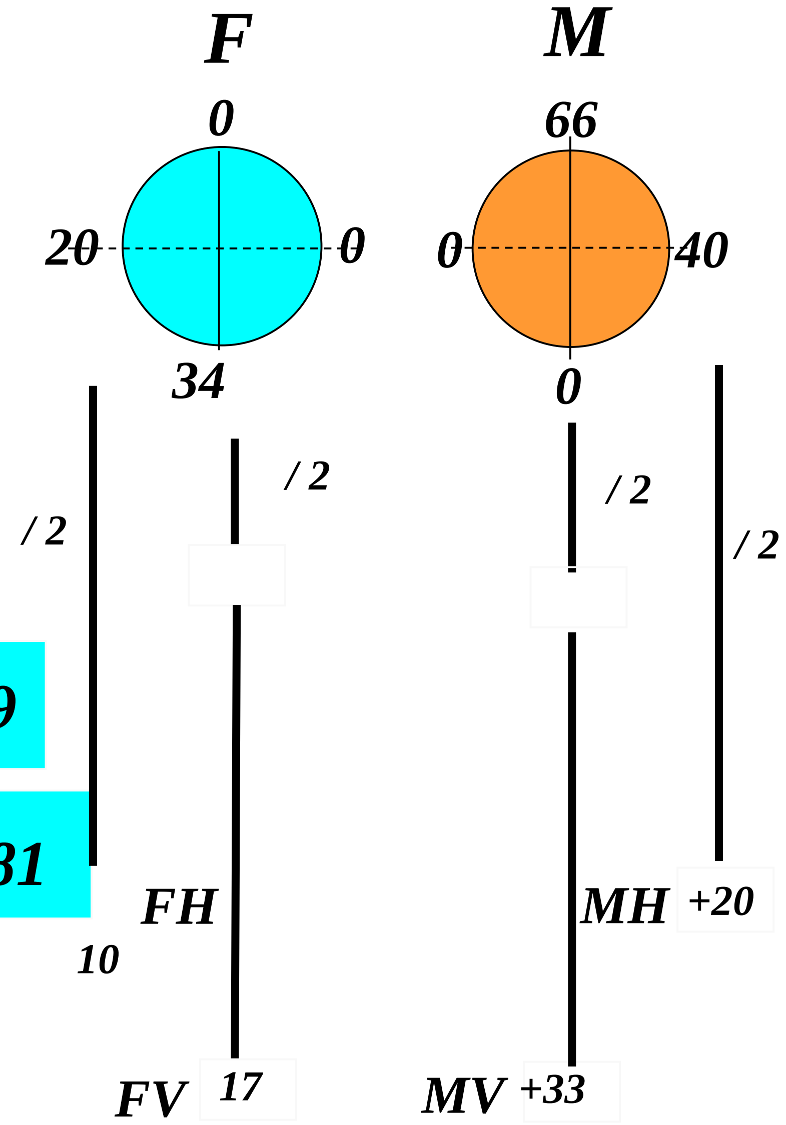
INBOARD $= \left\{ 33 - 17 \right\} \dfrac{8}{4} + 17 = + 49$

OUTBOARD $= \left\{ 33 - 17 \right\} \dfrac{16}{4} + 17 = + 81$

HORIZONTALLY

INBOARD $= \left\{ 20 - 10 \right\} \dfrac{8}{4} + 10 = + 30$

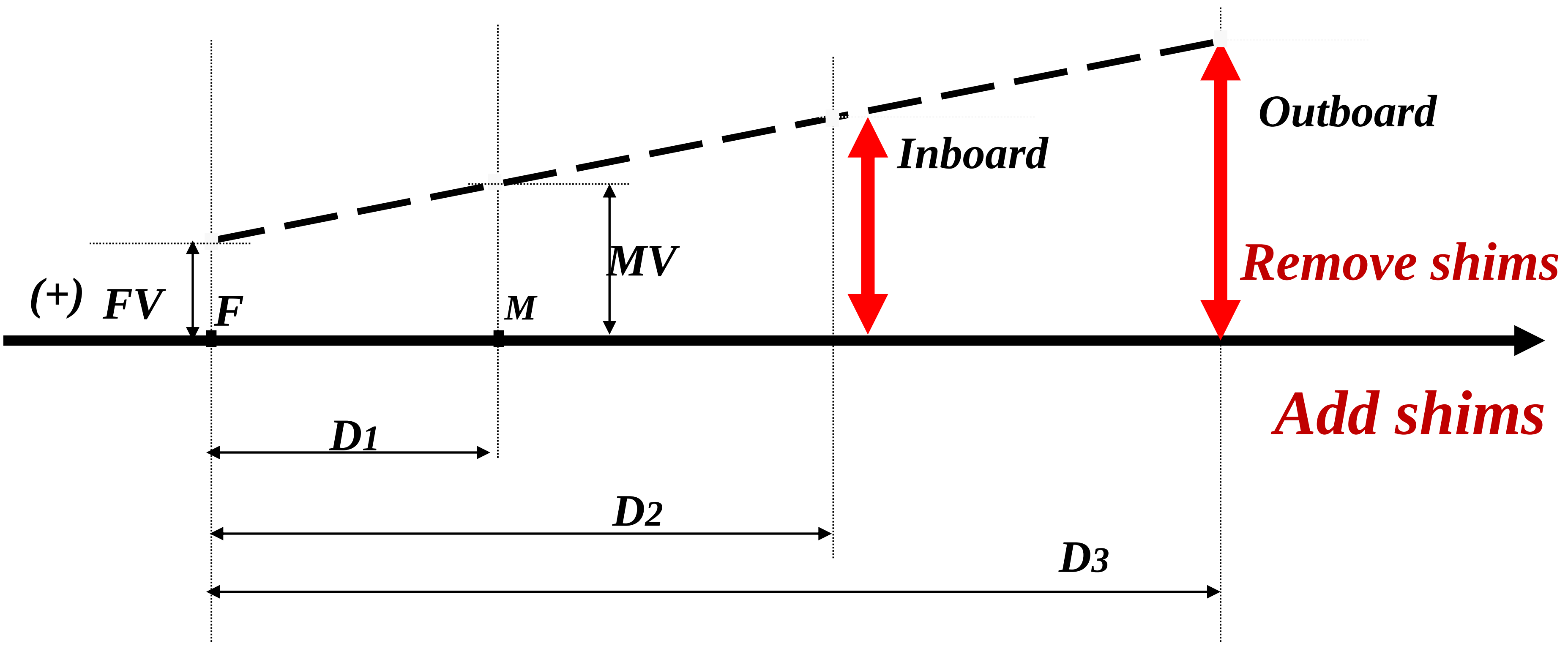
OUTBOARD $= \left\{ 20 - 10 \right\} \dfrac{16}{4} + 10 = + 50$



Mils

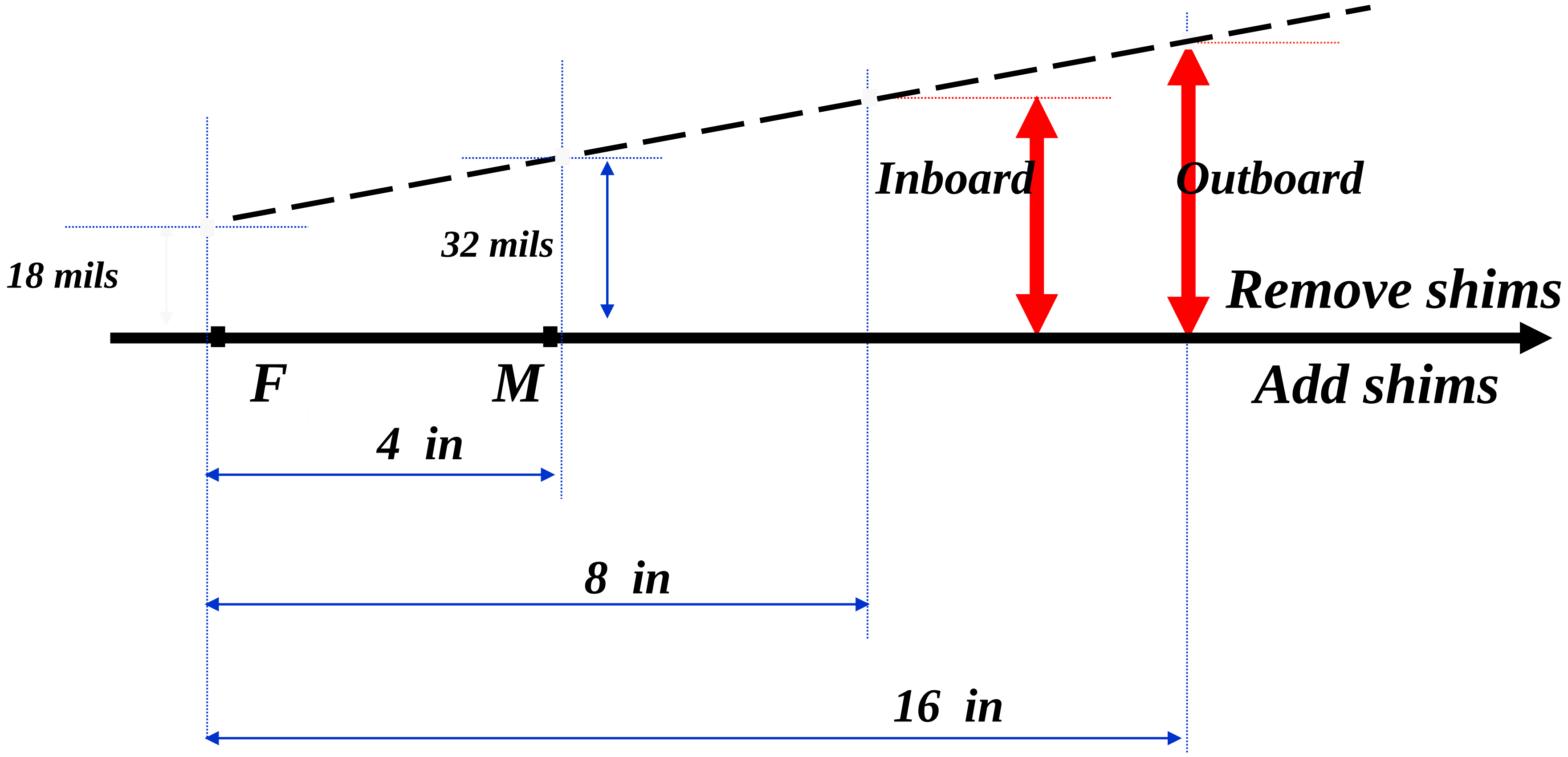
Reversal Alignment Graphical Method

Vertically

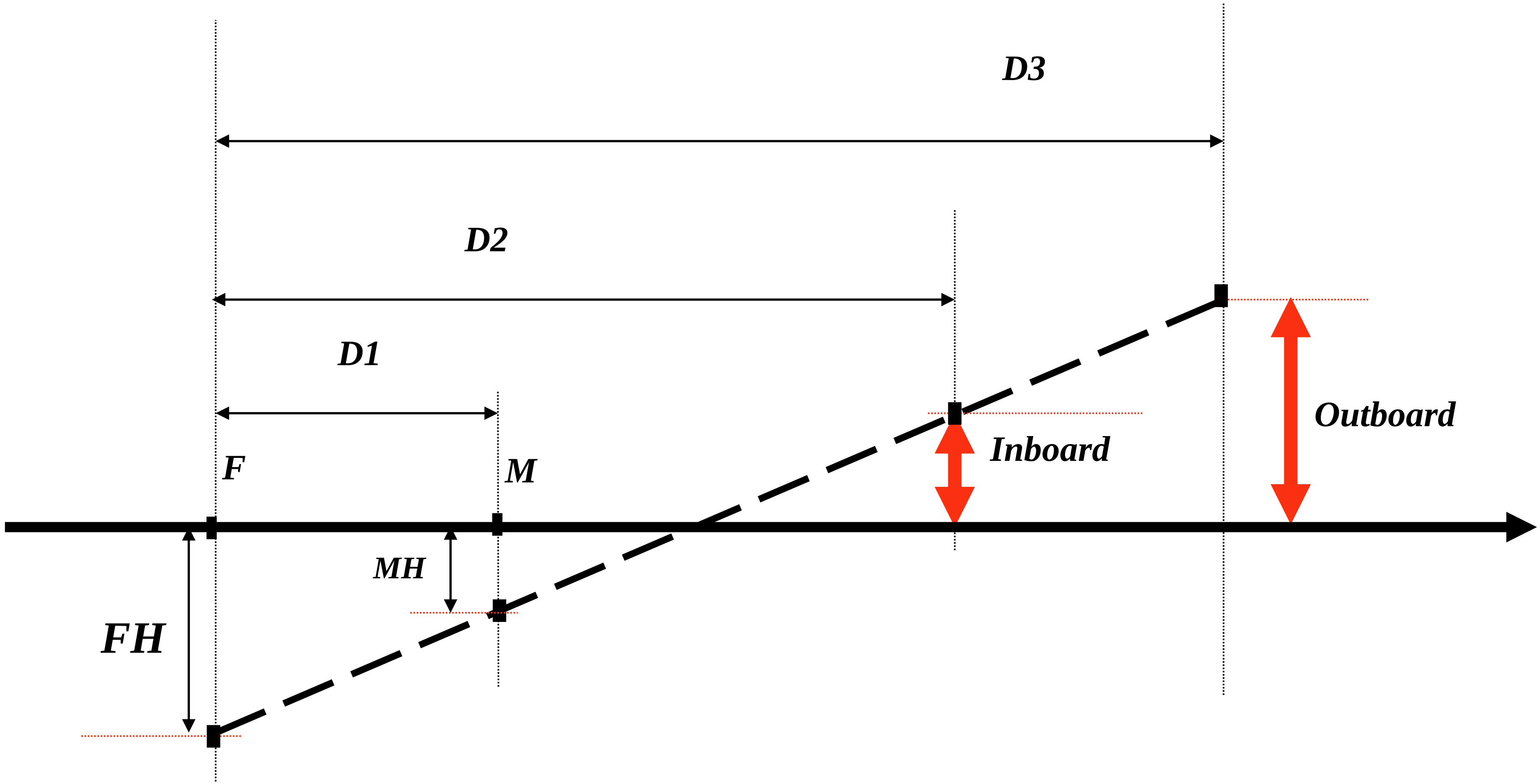


Vertically

FV = 18 mils
MV = 32 mils

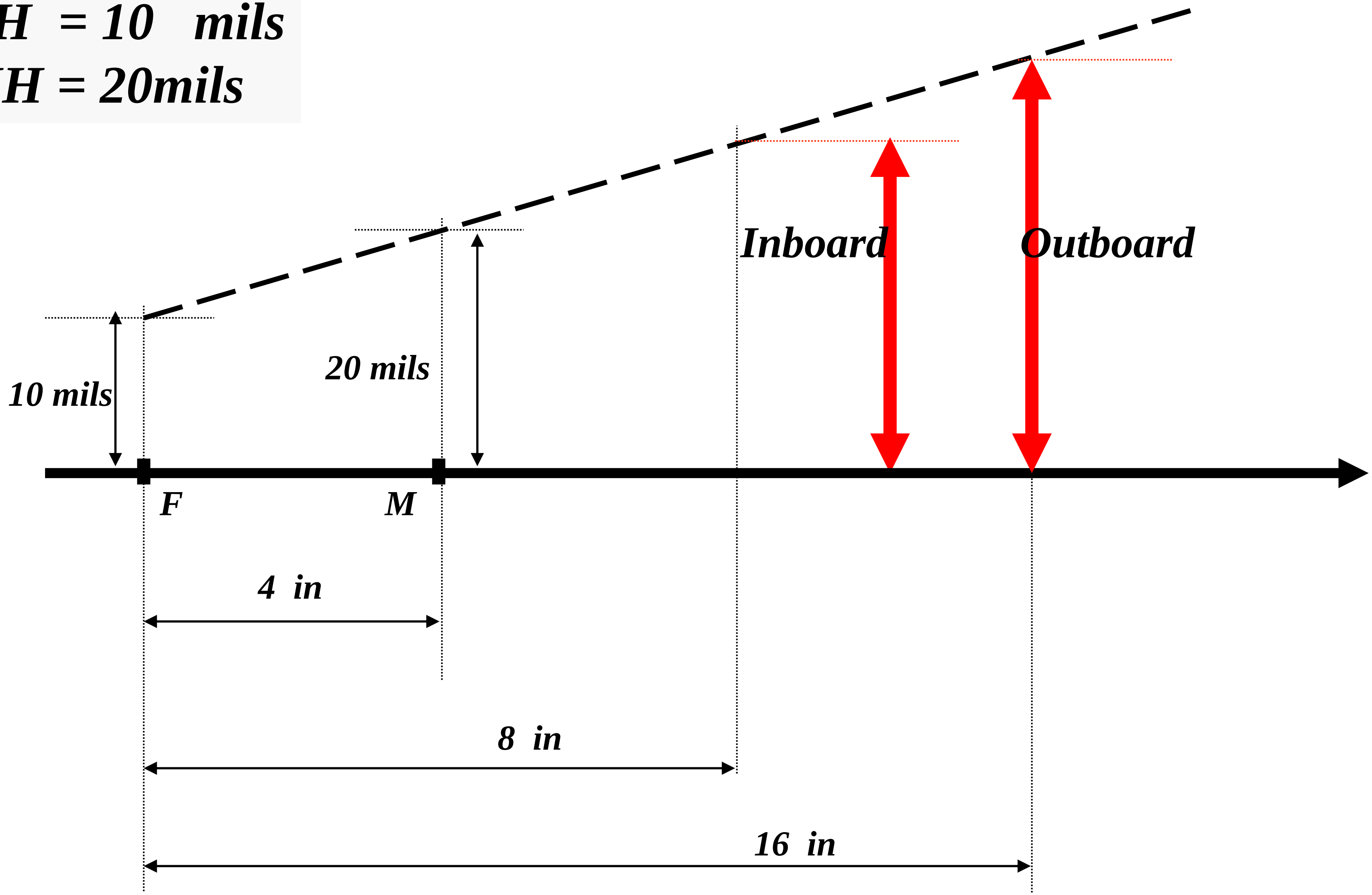


Horizontally



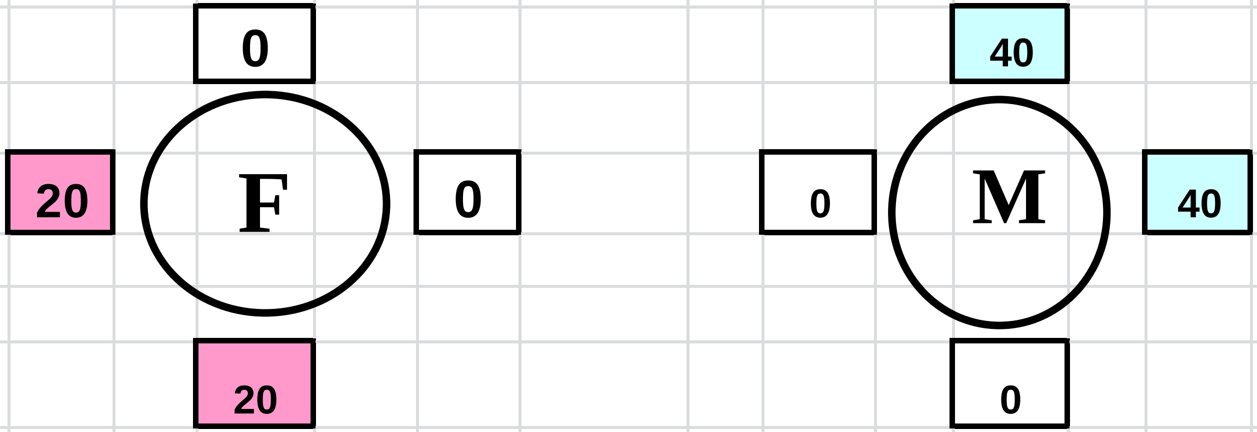
EXAMPLE

FH = 10 mils
MH = 20mils



3-Reversal Alignment Software

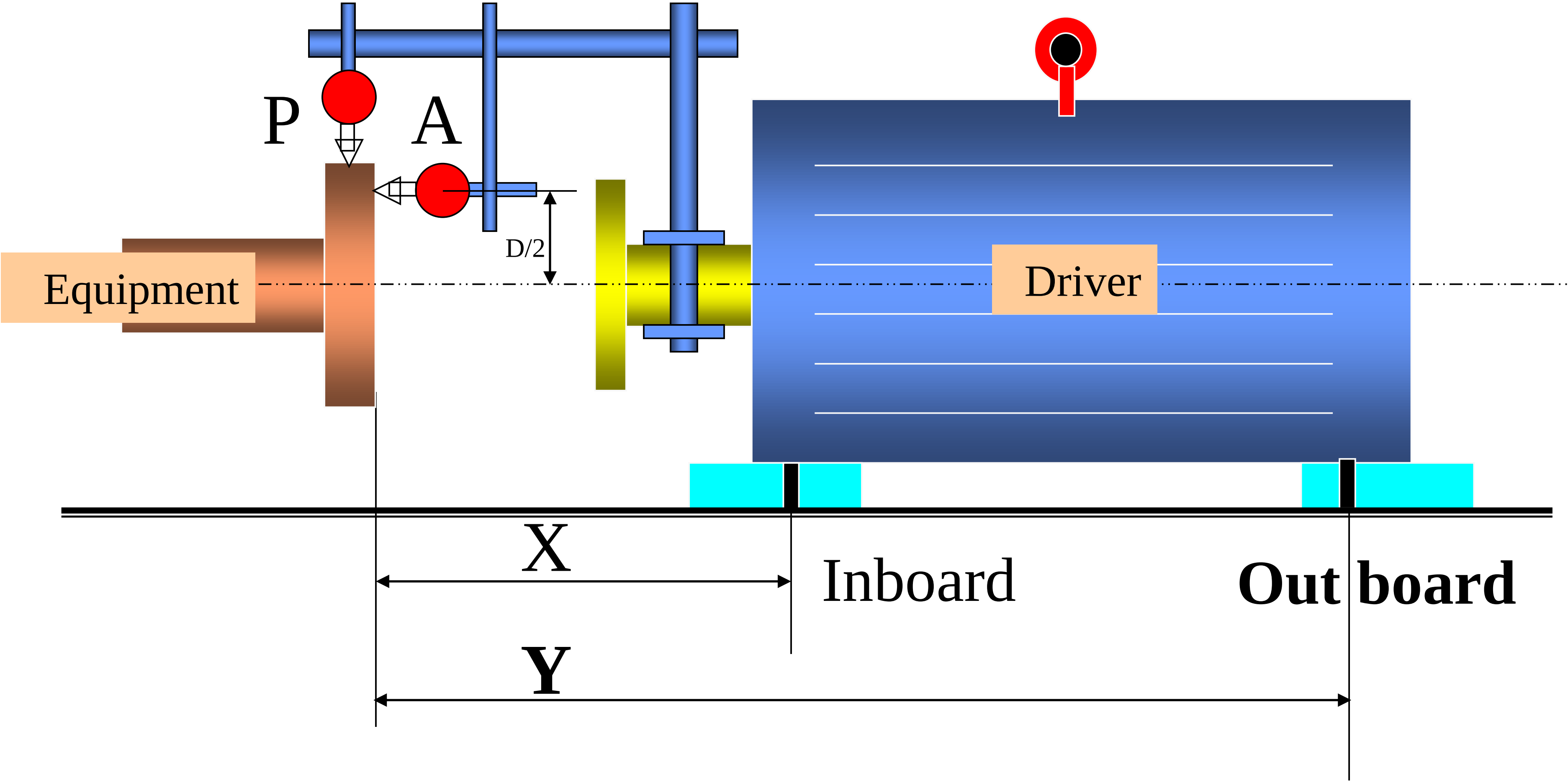
D1	D 2	D 3	Sag Factor(F)	Factor (M)
2	4	8	0	0



Inboard	**(vertical)**	**30**	**0**	REMOVE shims
Outboard	**(vertical)**	**50**	**0**	REMOVE shims
Inboard	**(Horiz.)**	**30**	0	Move towards 9
Outboard	**(Horiz)**	**50**	0	Move towards 9

Rim and Face Alignment

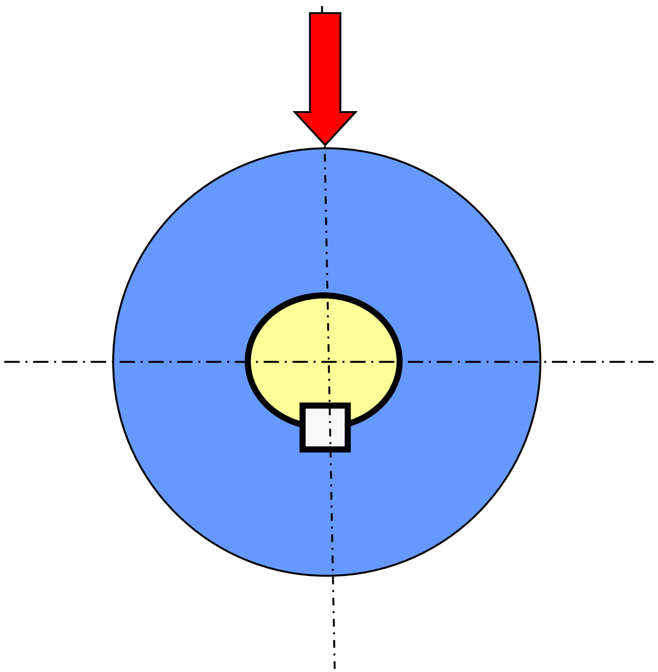
P = **P**arallel Reading
A = **A**ngular Reading



PARALELL READING

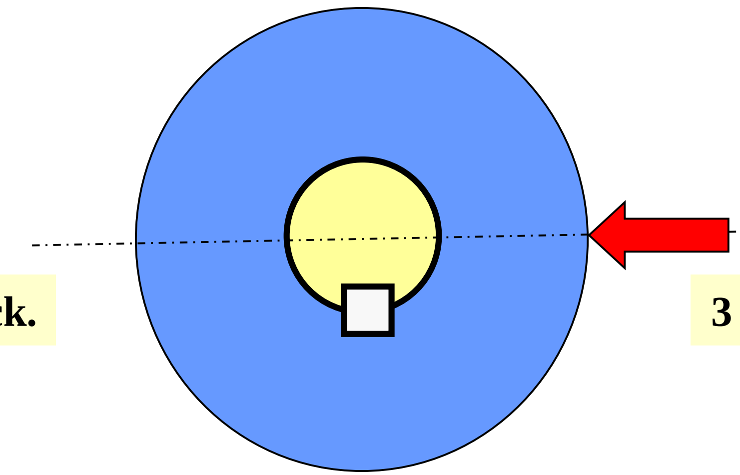
VERTICAL

12 Ock



6 Ock

HORIZONTAL

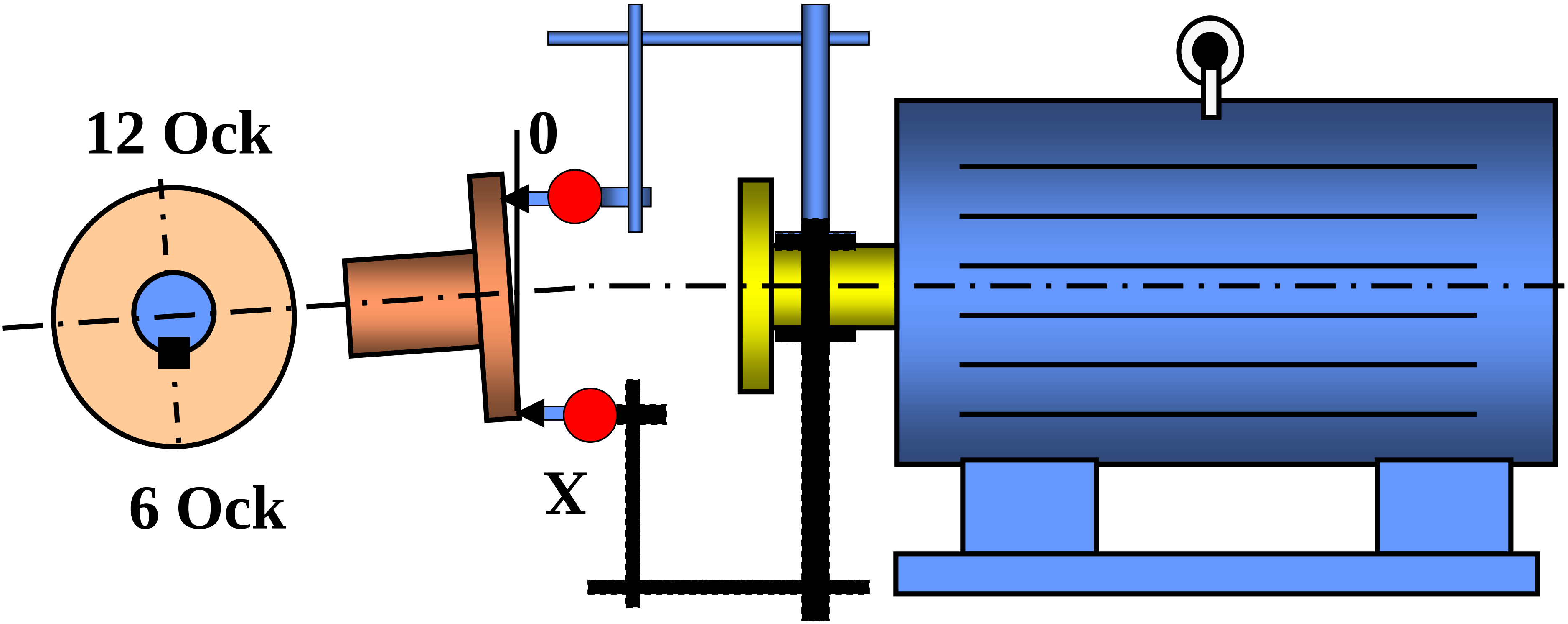


9 Ock.

3 Ock

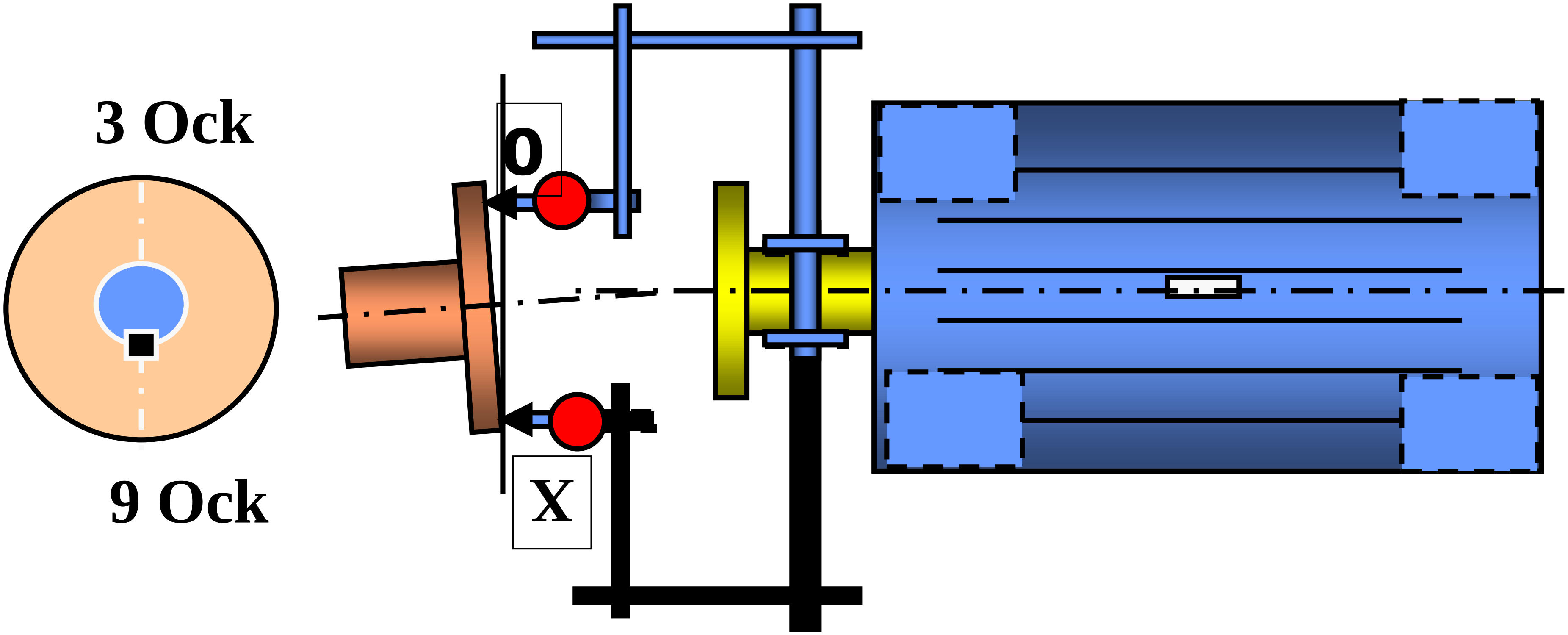
Angular Reading

VERTICAL

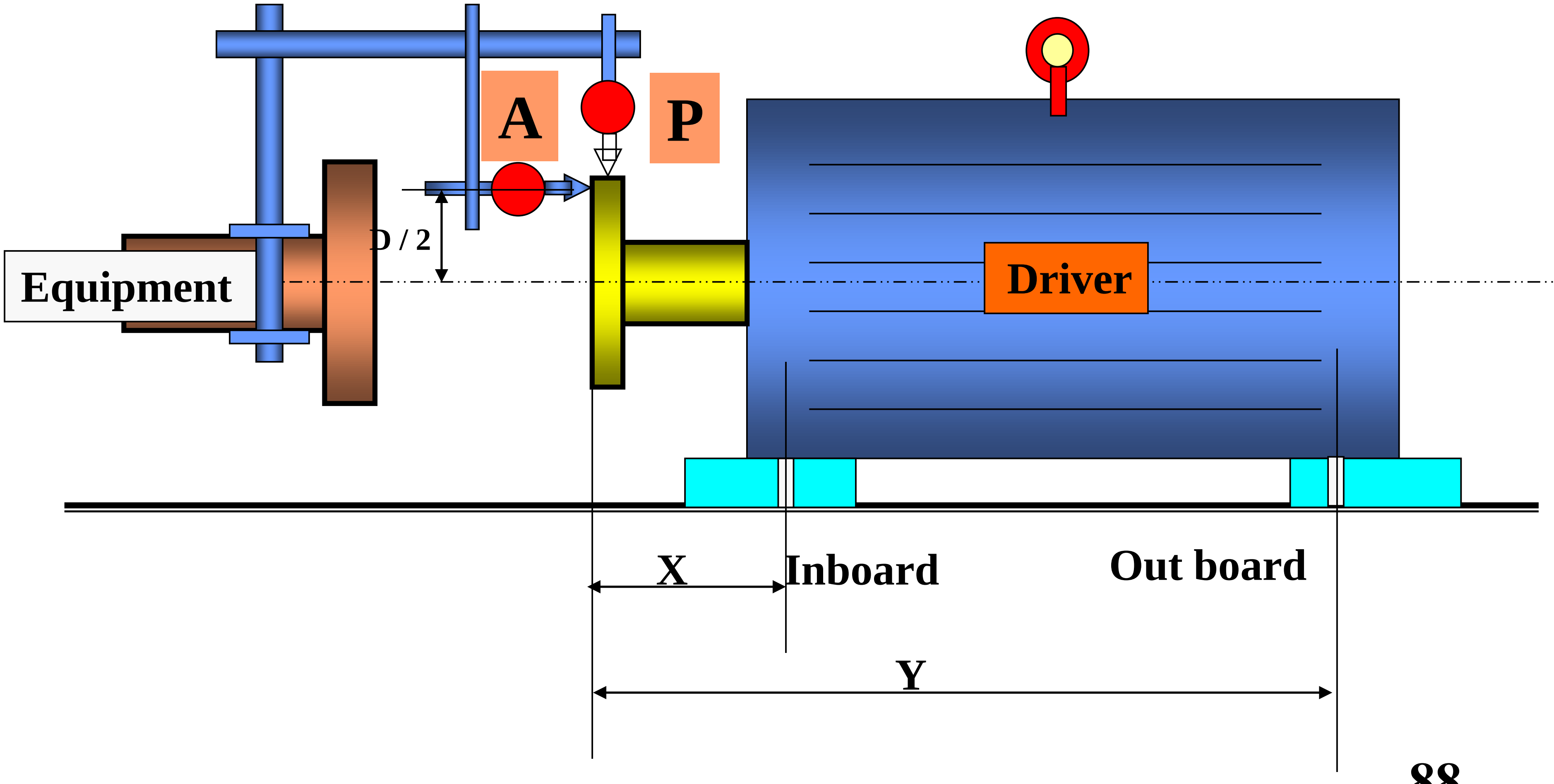


Angular Reading

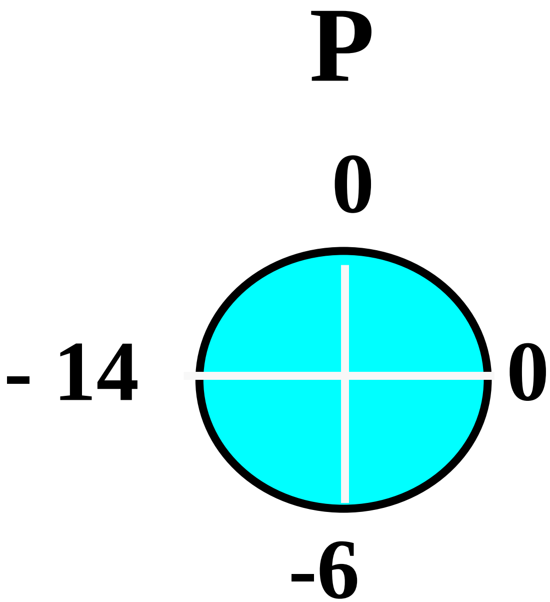
Horizontal

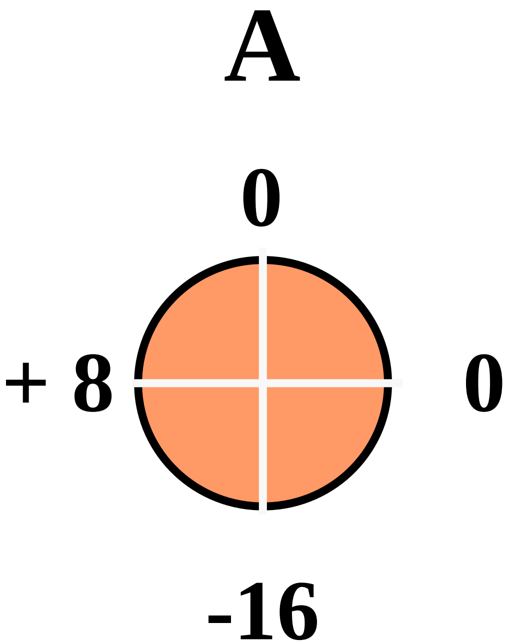


OR



CALCULATION METHOD





P = PARALLEL READING

A = ANGULAR READING

X =

Y =

D =

Sag = - 1

VERTICALLY

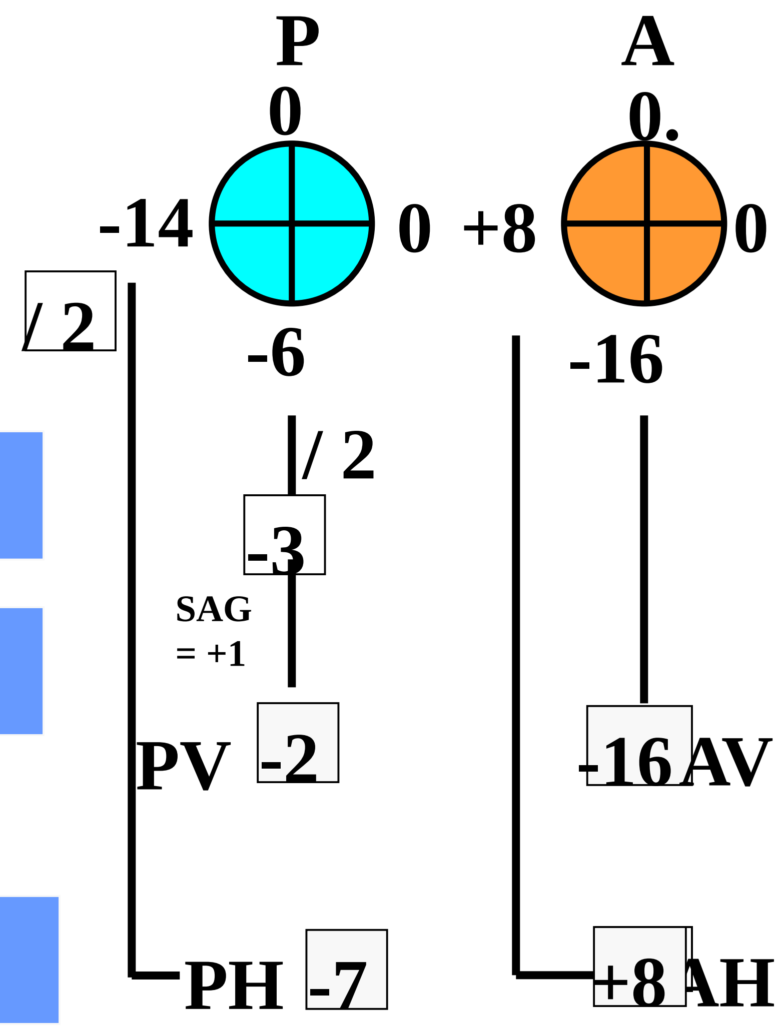
INBOARD $= \left[\frac{X}{D} \times AV \right] - PV$ **Mils**

OUTBOARD $= \left[\frac{Y}{D} \times AV \right] - PV$ **Mils**

HORIZONTALLY

INBOARD $= \left[\frac{X}{D} \times AH \right] - PH$ **Mils**

OUTBOARD $= \left[\frac{Y}{D} \times AH \right] - PH$ **Mils**

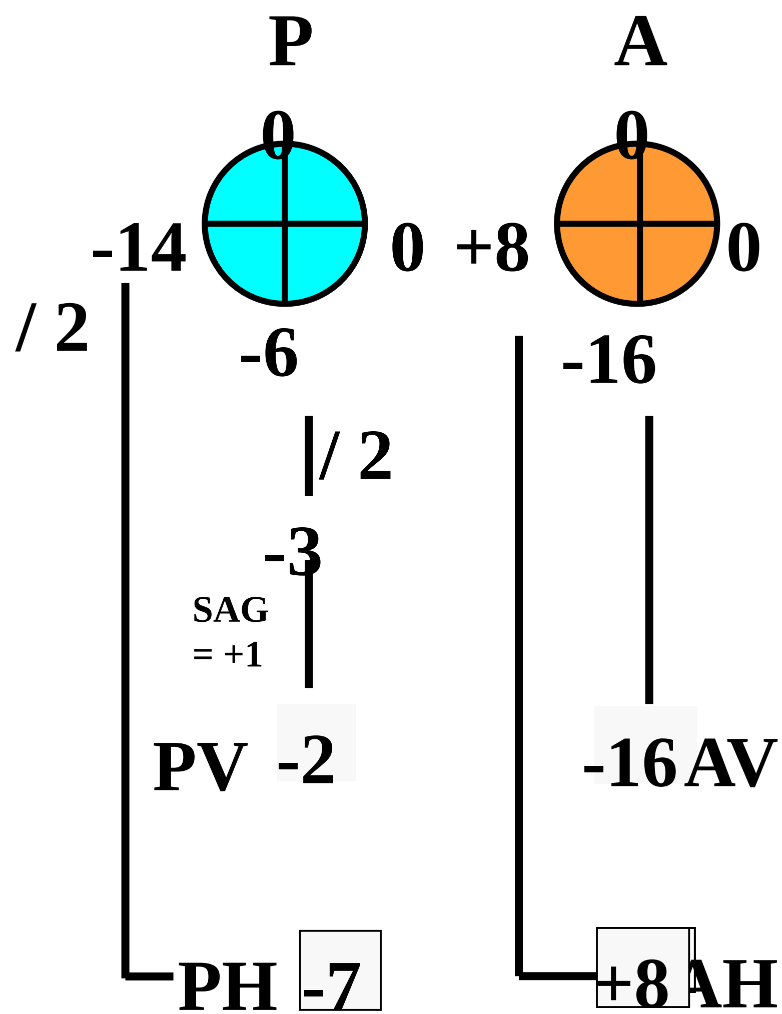


X = 4 in

Y = 12 in

D = 4 in

Sag = -1



VERTICALLY

INBOARD $= \left\{\frac{4}{4} \times -16\right\} - (-2) = -14$

OUTBOARD $= \left\{\frac{12}{4} \times -16\right\} - (-2) = -46$

HORIZONTALLY

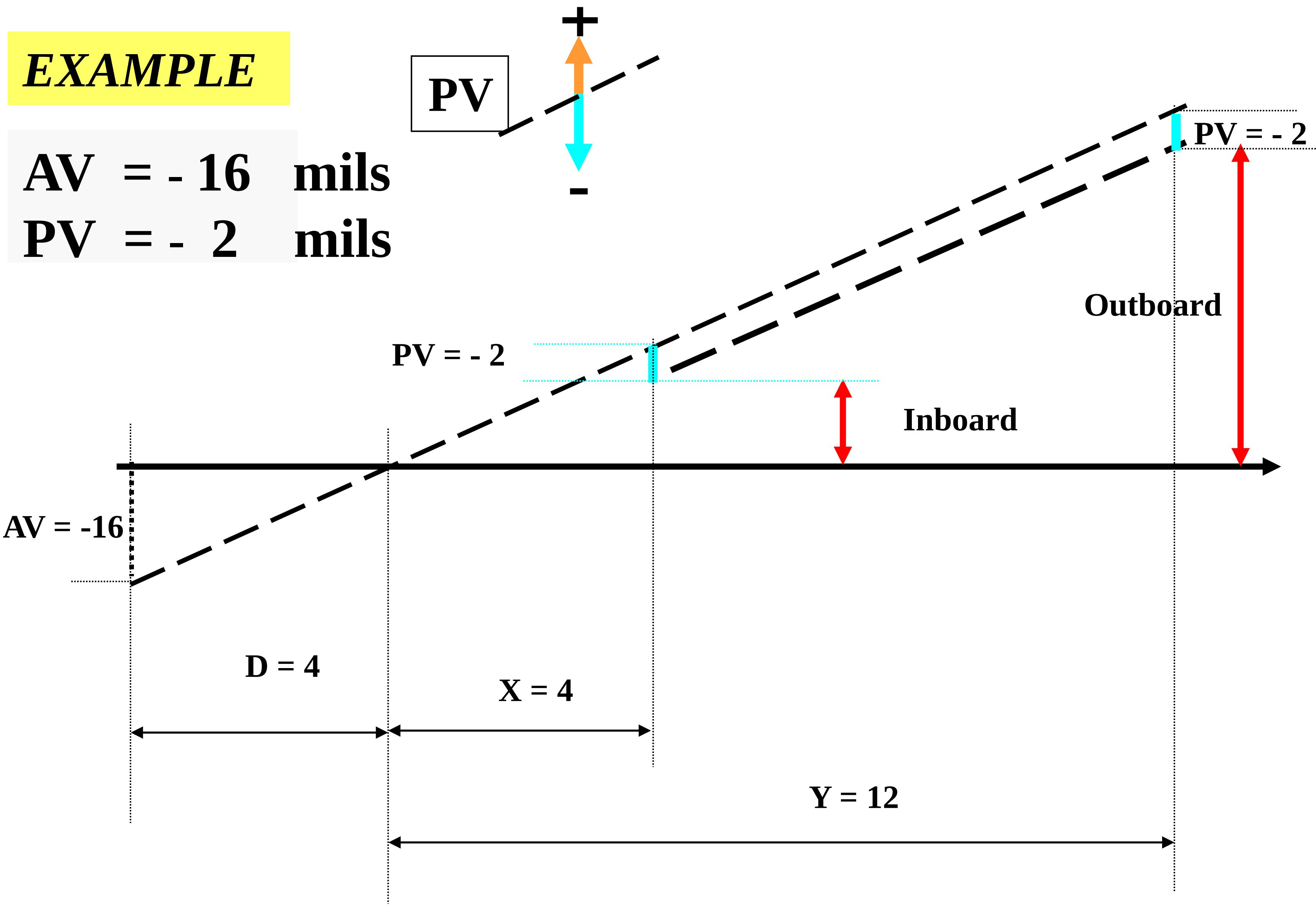
INBOARD $= \left\{\frac{4}{4} \times 8\right\} - (-7) = +15$

OUTBOARD $= \left\{\frac{12}{4} \times 8\right\} - (-7) = +31$

Mils

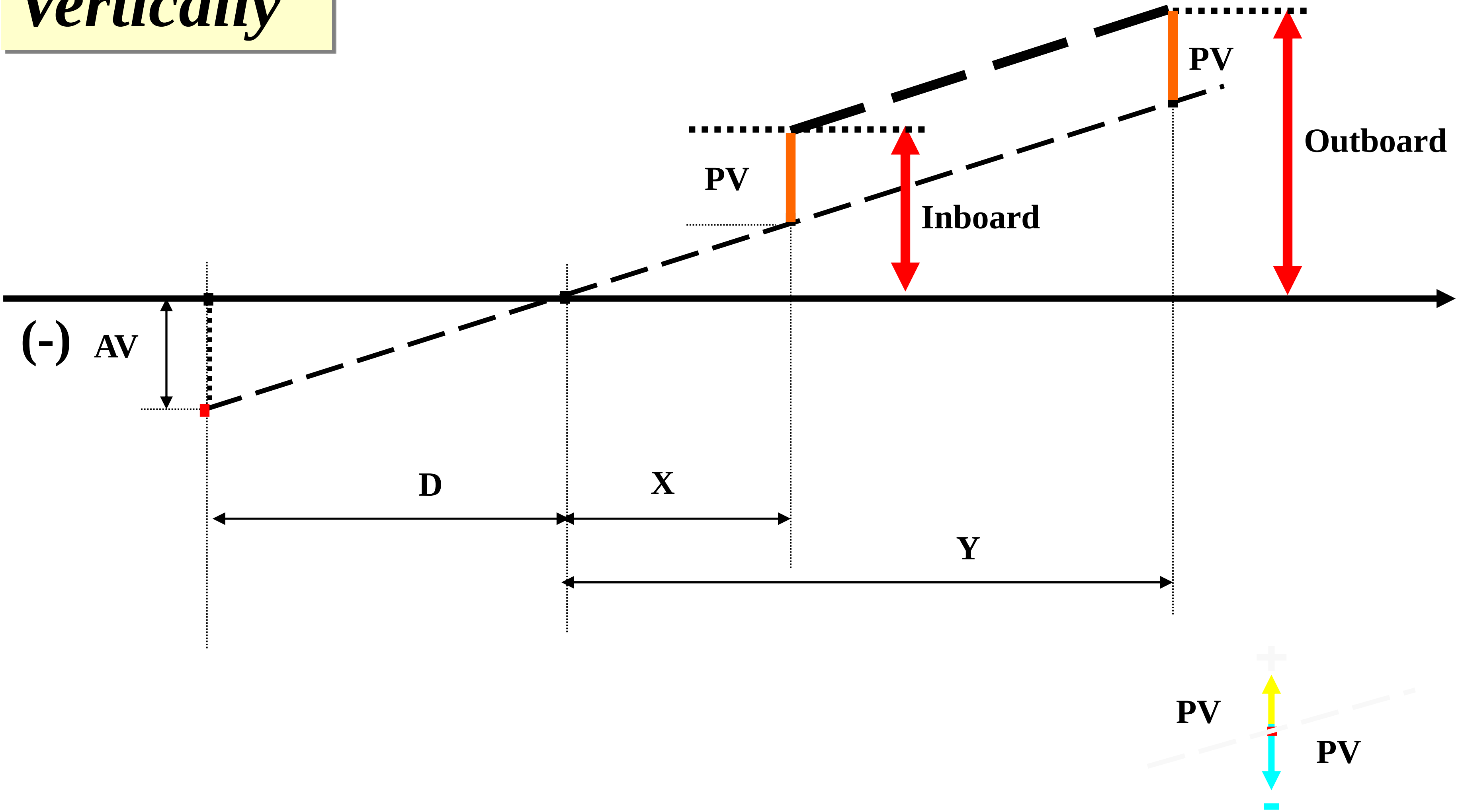
EXAMPLE

AV = - 16 mils
PV = - 2 mils

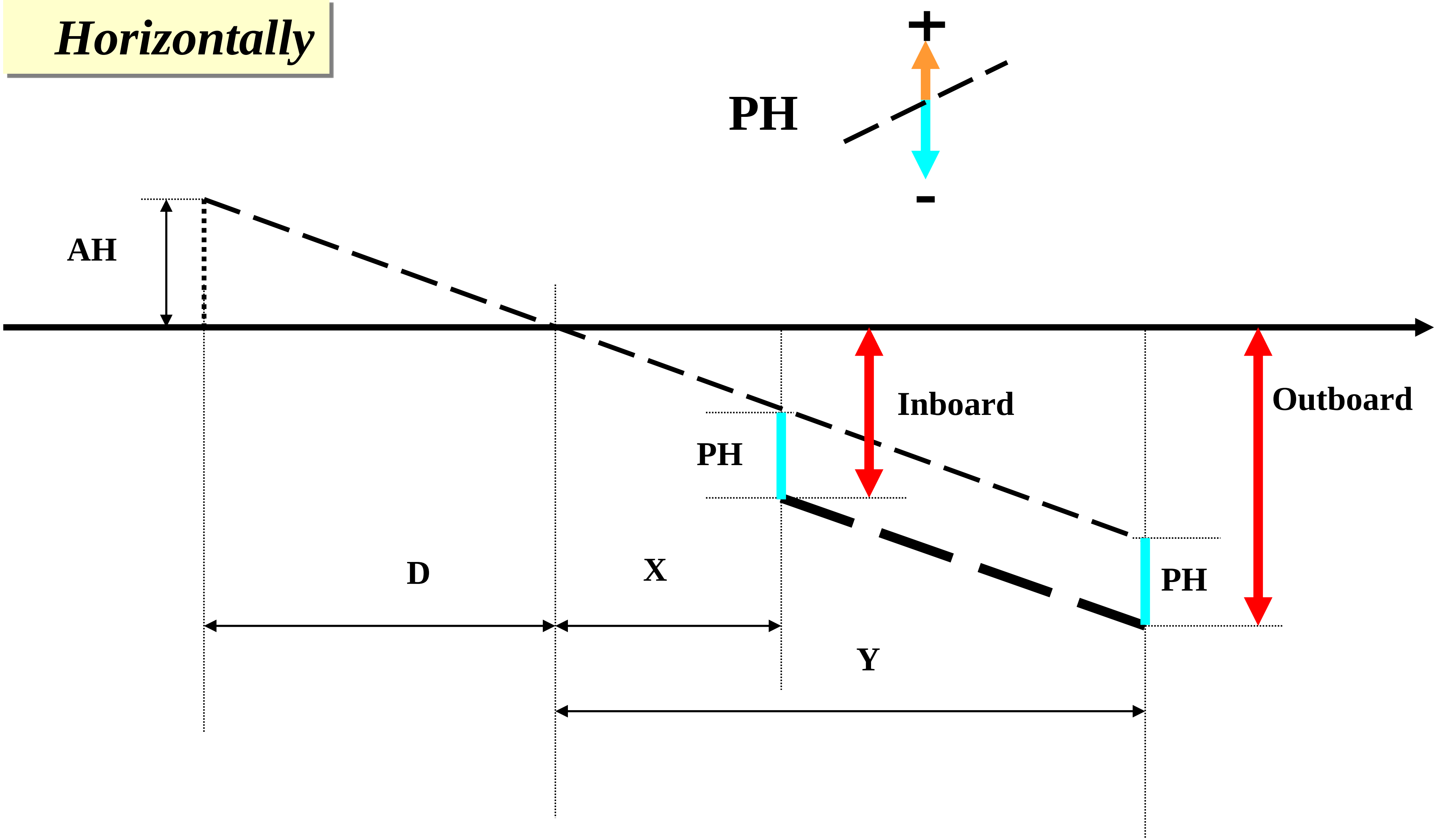


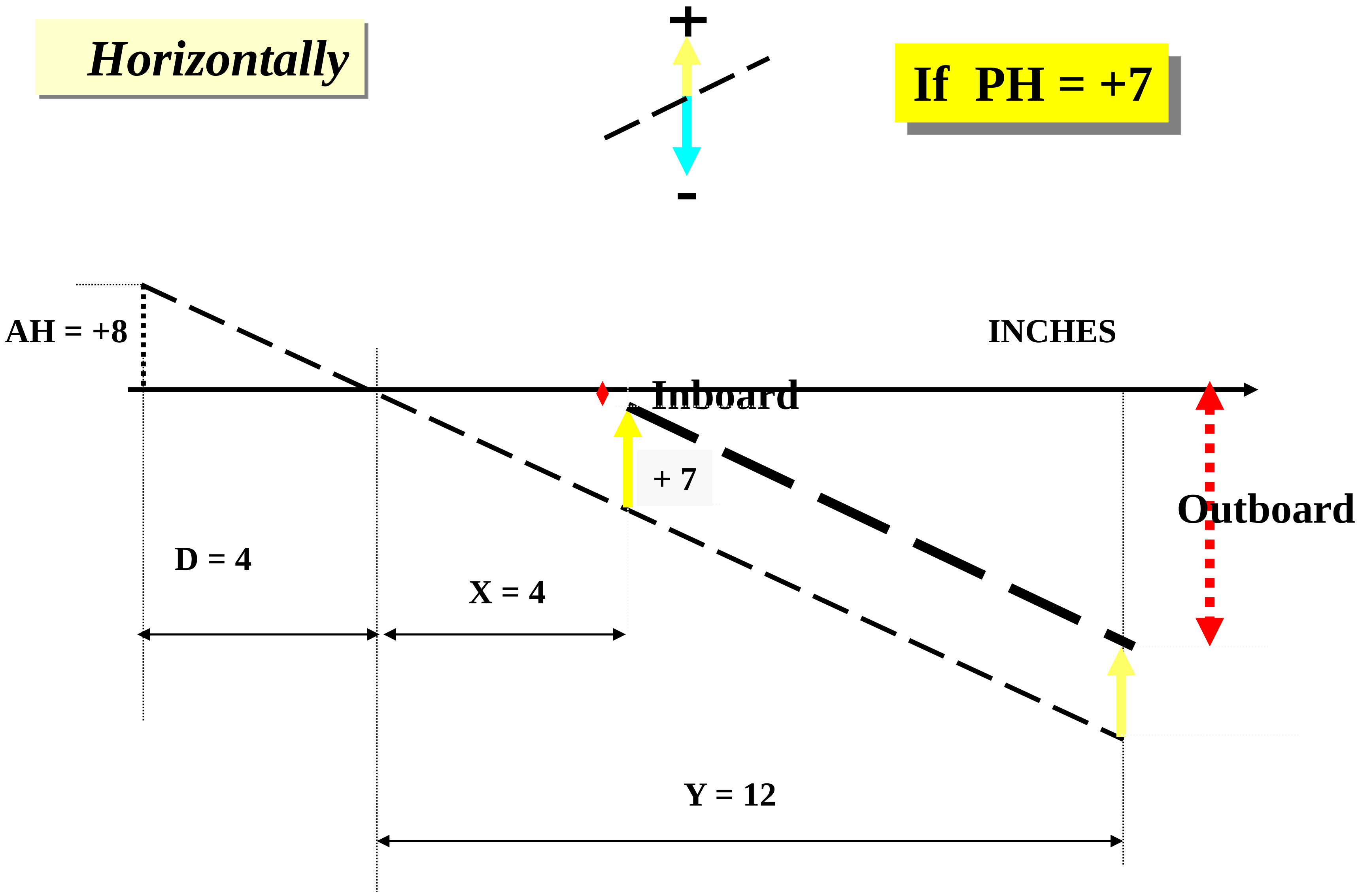
Graphical Method

Vertically



Horizontally

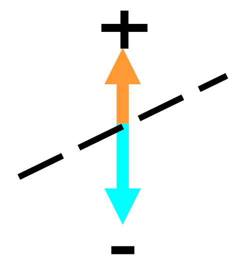




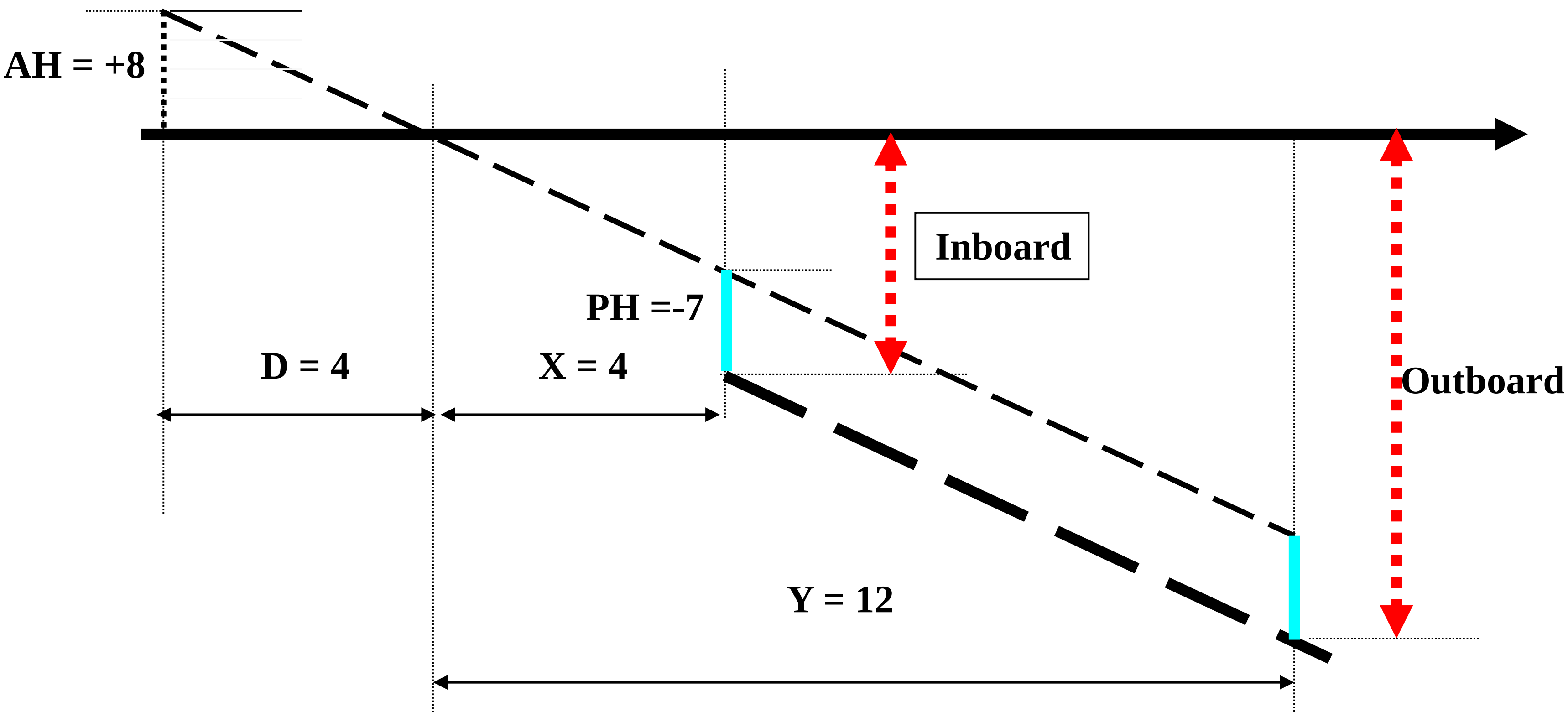
Horizontally
+
-
If PH = +7
AH = +8
INCHES
Inboard
+ 7
Outboard
D = 4
X = 4
Y = 12

EXAMPLE

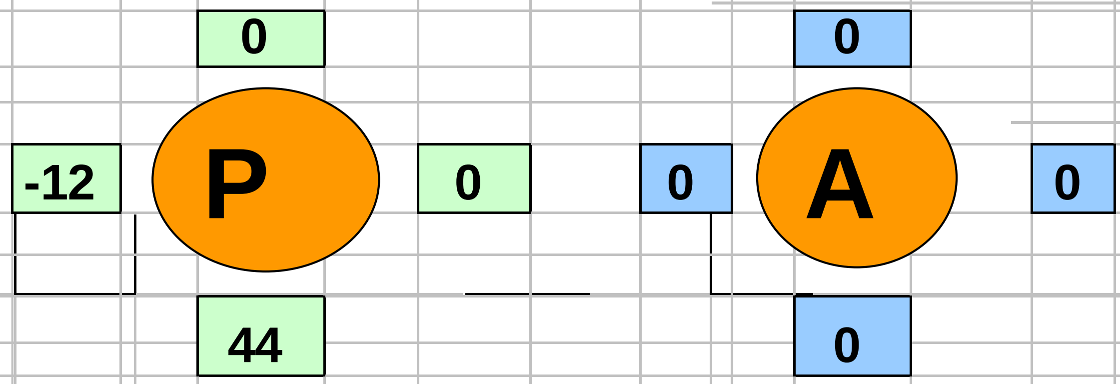
PH = - 7 mils
AH = + 8 mils



PH = - 7

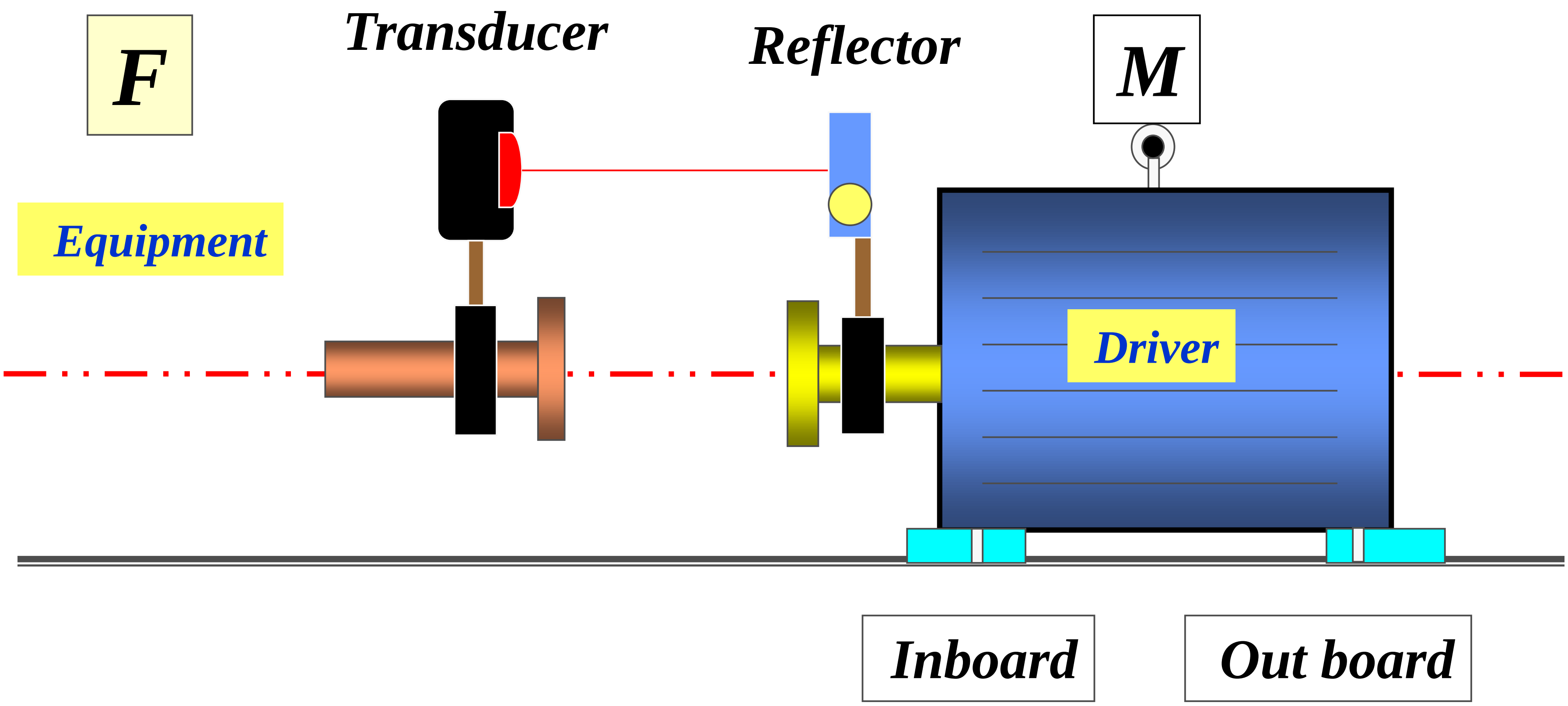


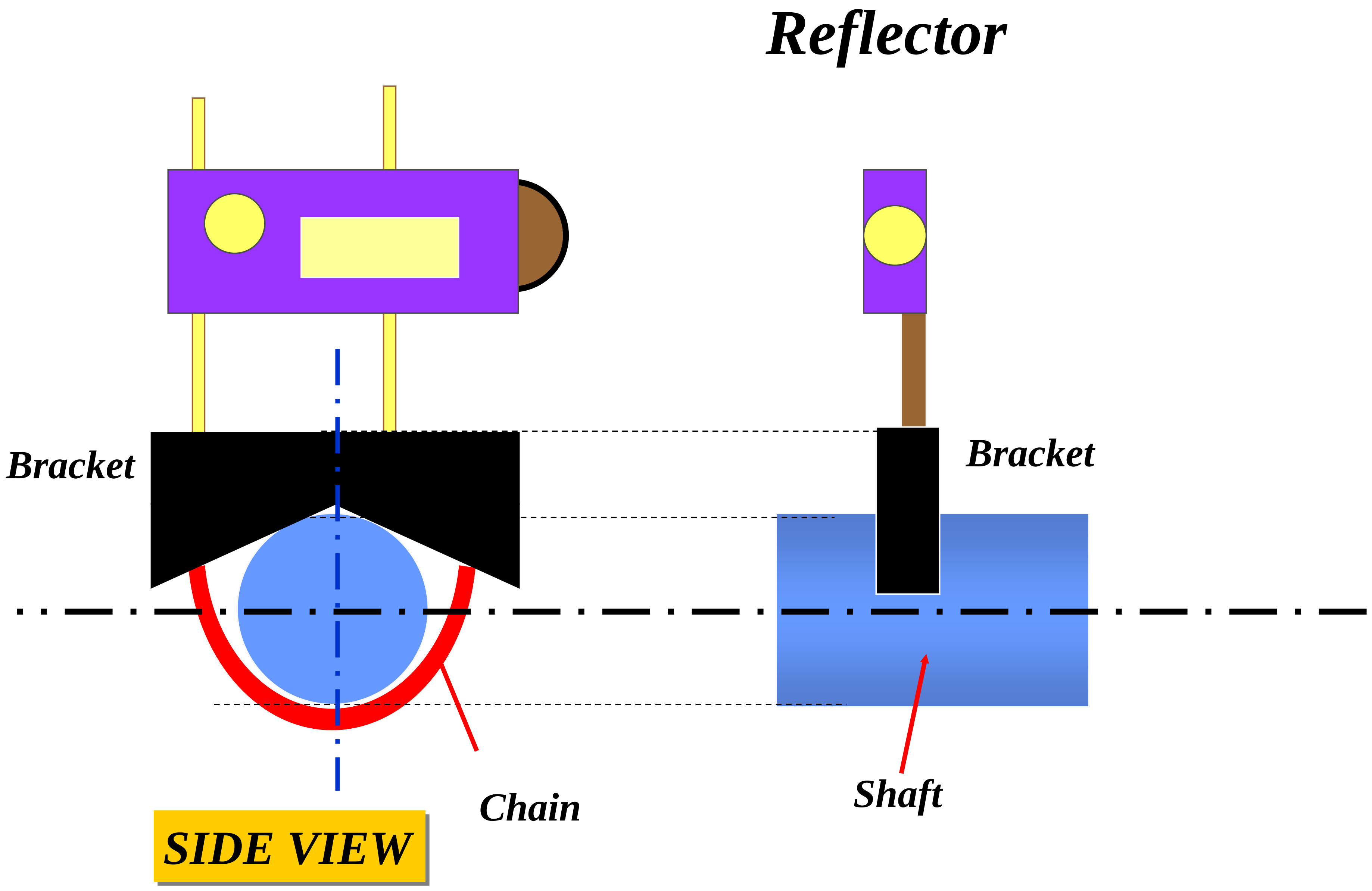
D	X	Y	Sag
2	4	8	0

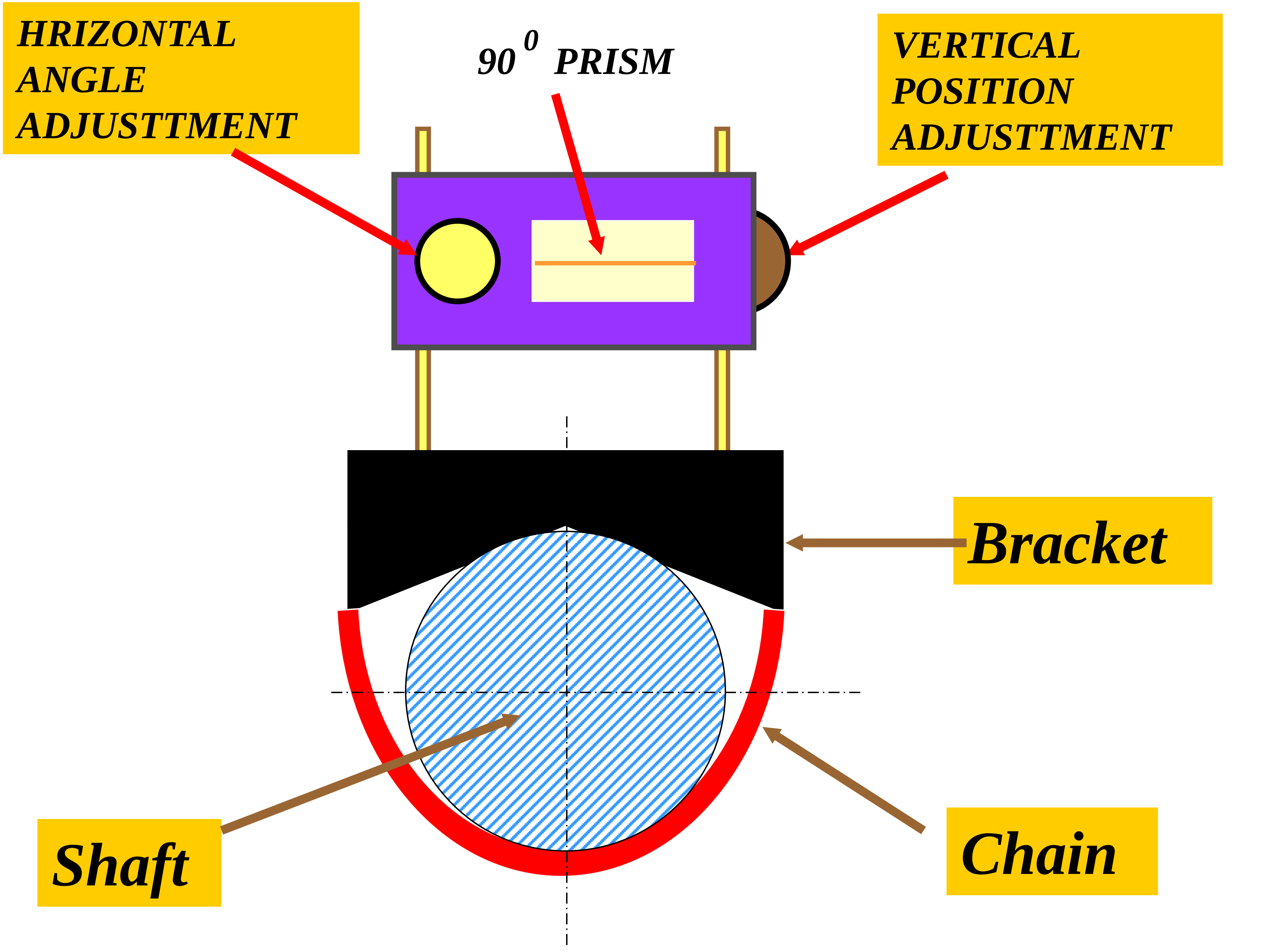


Inboard (Vertical)	-22	→	Remove Shims	0
Outboard (Vertical)	-22	→	Remove Shims	0
Inboard (Horizontal)	6	→	0	Move to 3 O'clock
Outboard (Horizontal)	6	→	0	Move to 3 O'clock

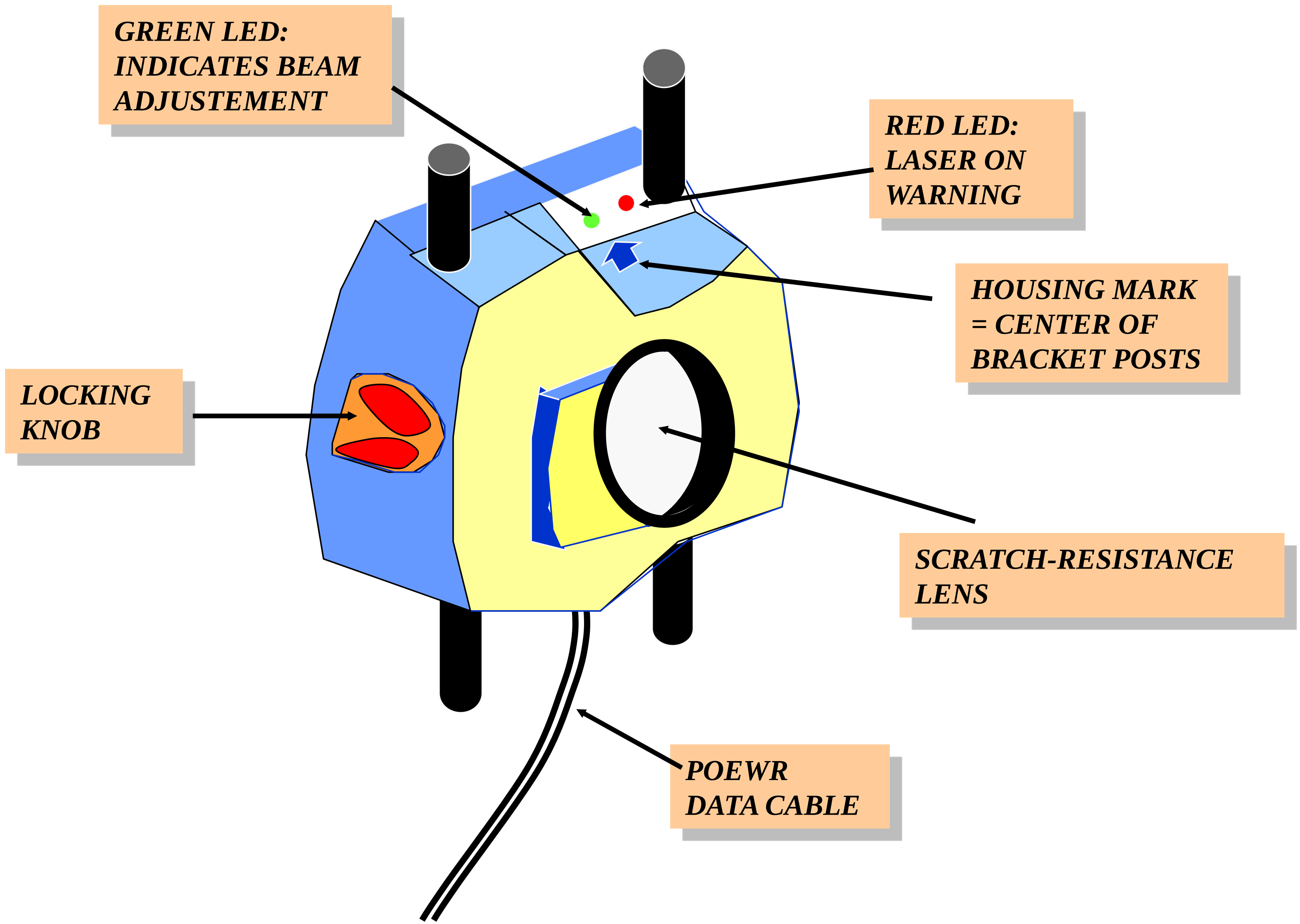
Optical Alignment




Reflector
Bracket
Bracket
Chain
Shaft
SIDE VIEW


HRIZONTAL ANGLE ADJUSTTMENT
90 0 PRISM
VERTICAL POSITION ADJUSTTMENT
Bracket
Shaft
Chain

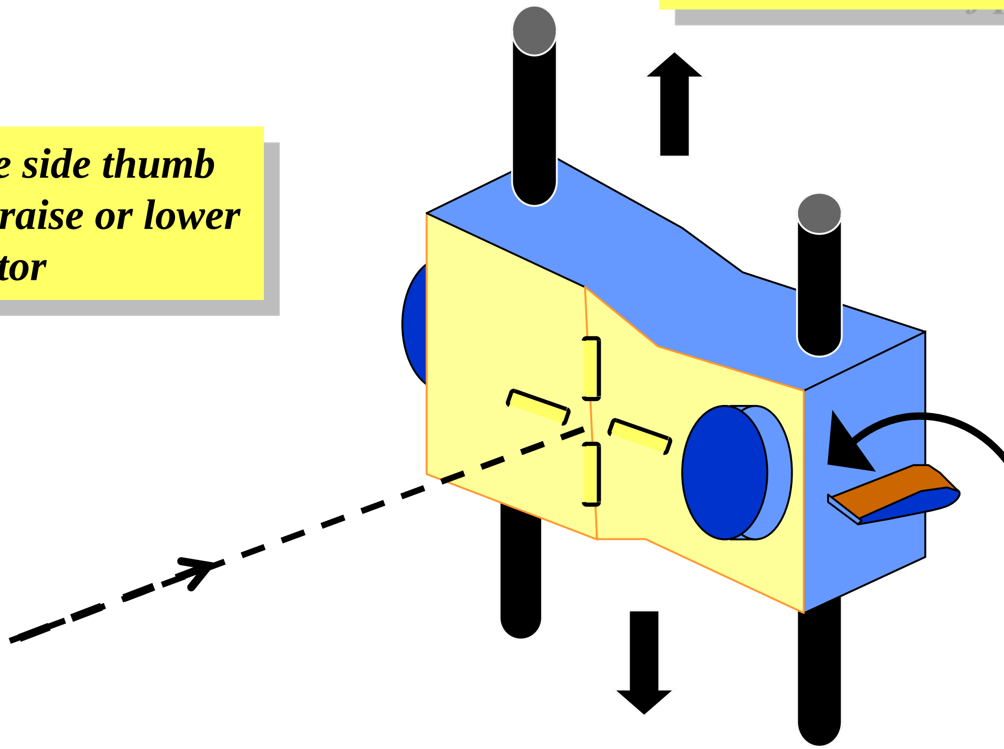
Transducer


GREEN LED:
INDICATES BEAM
ADJUSTEMENT
RED LED:
LASER ON
WARNING
HOUSING MARK
= CENTER OF
BRACKET POSTS
LOCKING
KNOB
SCRATCH-RESISTANCE
LENS
POEWR
DATA CABLE

REFLECTOR

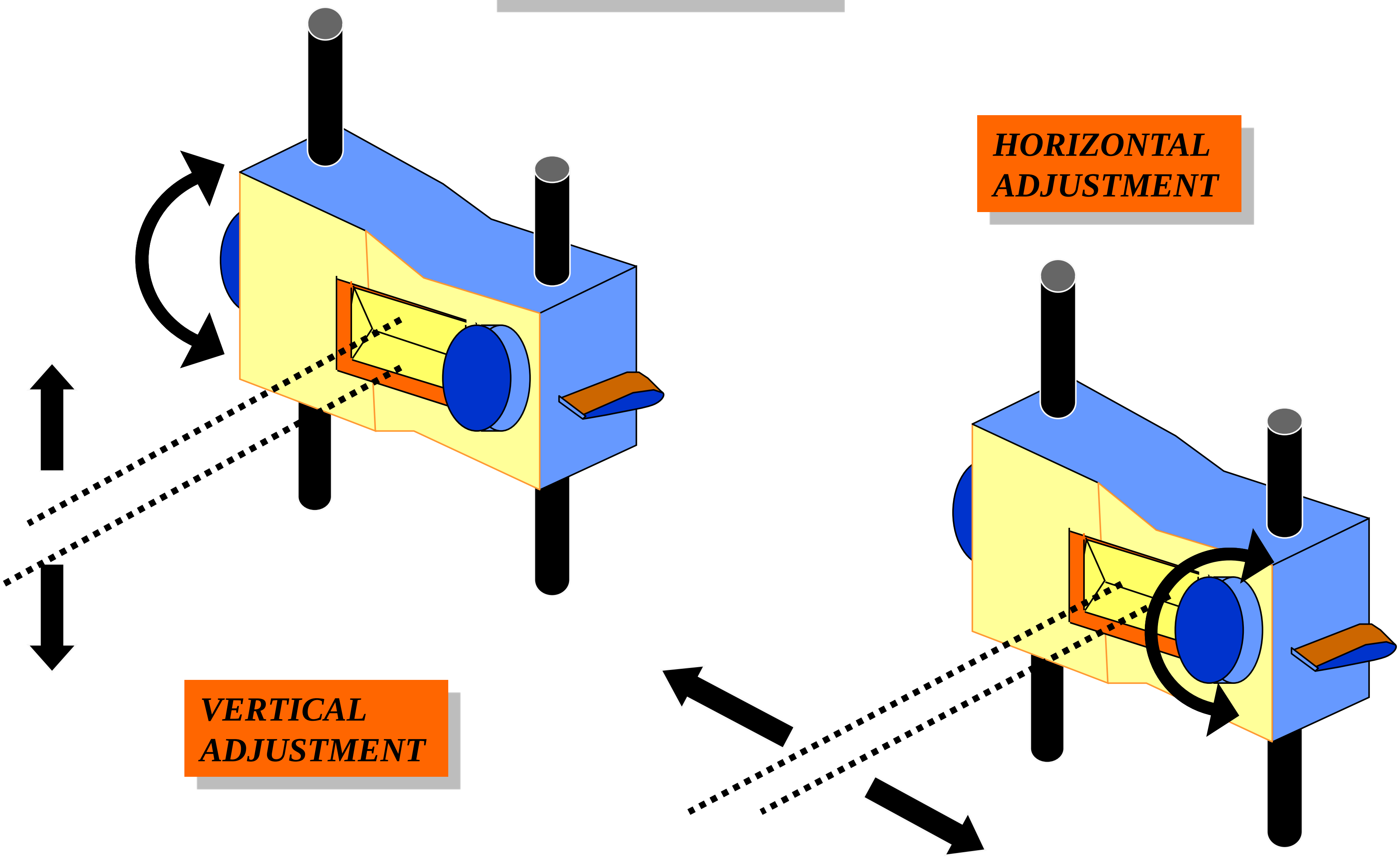
1- PRESS M and remove transducer cap.
-The laser beam now is on.
-Leave the reflector cap on for now.
-Beam strikes the cap, it should be visible.
- Hold a sheet of paper to locate the beam

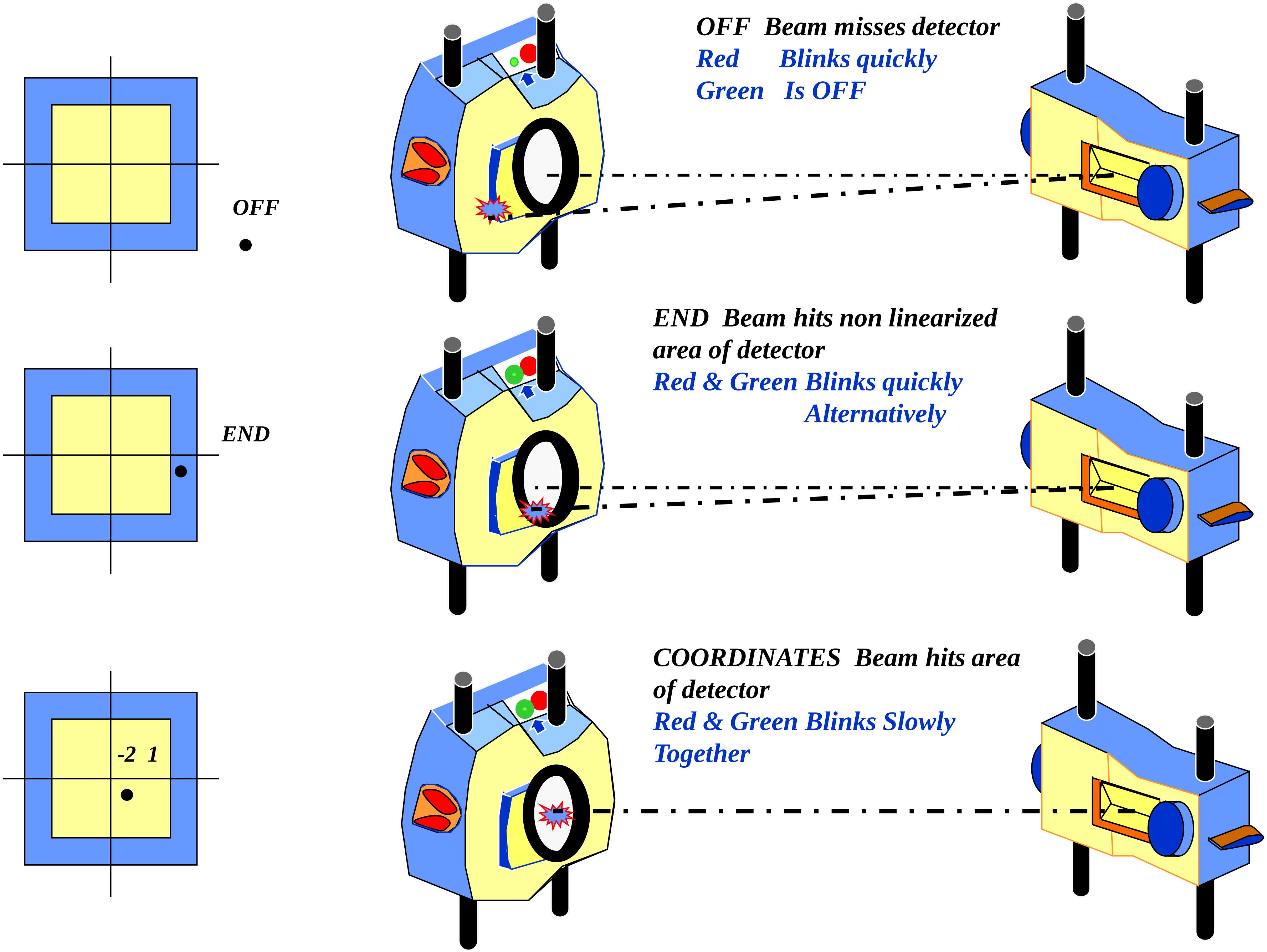
Rotate the side thumb
Wheel to raise or lower
the reflector



This lever to lock
The reflector position

REFLECTOR




OFF
OFF Beam misses detector
Red Blinks quickly
Green Is OFF
END
END Beam hits non linearized area of detector
Red & Green Blinks quickly Alternatively
-2 1
COORDINATES Beam hits area of detector
Red & Green Blinks Slowly Together

1- PREPARING FOR ALIGNMENT PROCEDURE

a- Solid flat foundation

b- Machine mobility (2 mm higher & screw type positioning)

c- Soft foot (Must be checked immediately)

d- Thermal growth

HORIZONTAL MACHINE ALIGNMENT

Select DIM **Cycle through with ◀ and ▶**

1-Transducer to reflector

2-Transducer to coupling center

3-Coupling diameter

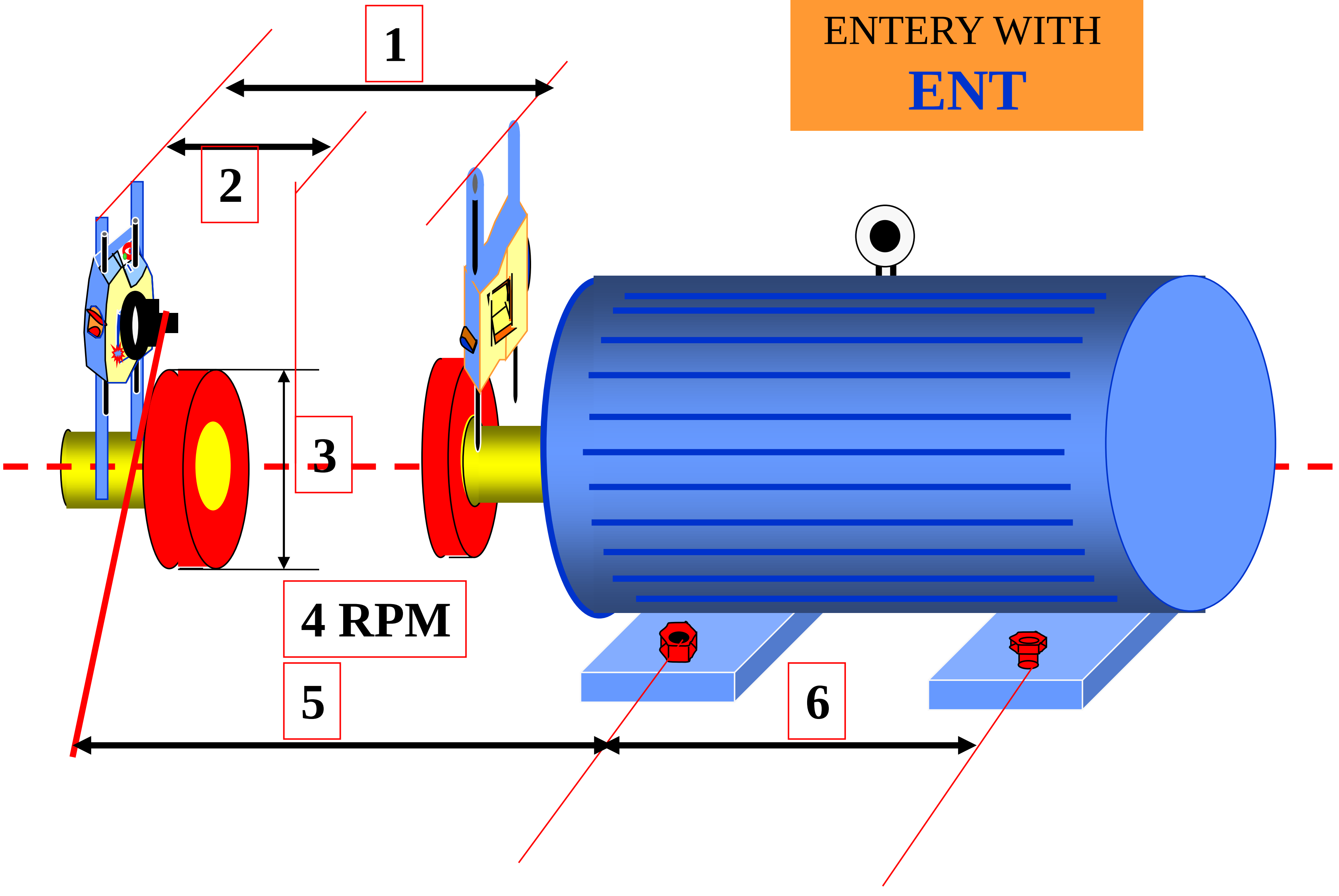
4-RPM

5-Transducer to front feet

6- Front feet to rear feet

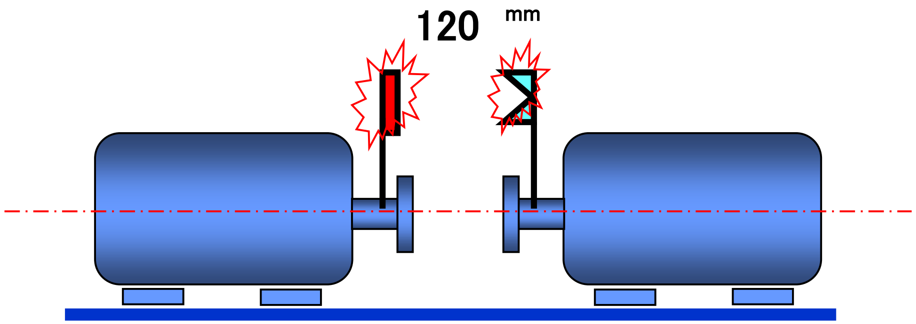
DIM

CONFIRM EACH ENTERY WITH **ENT**

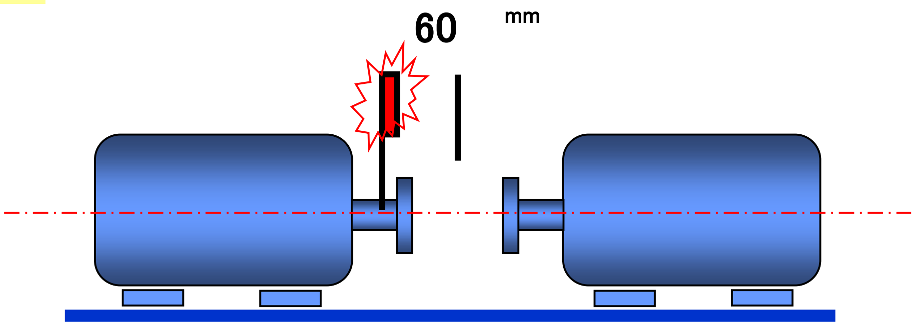


DIM

1-Transducer to reflector



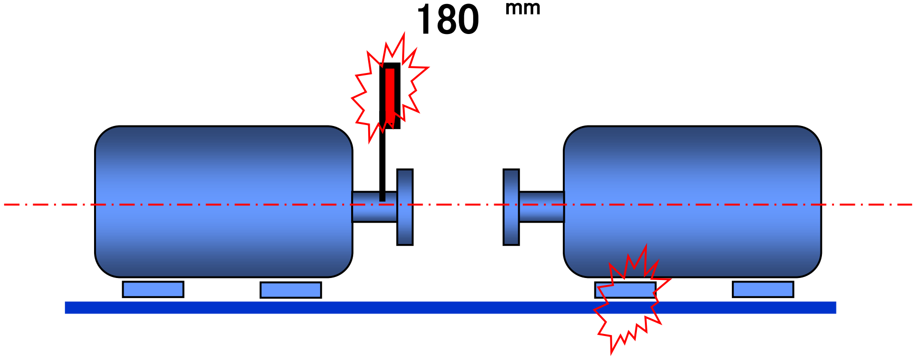
2-Transducer to coupling center



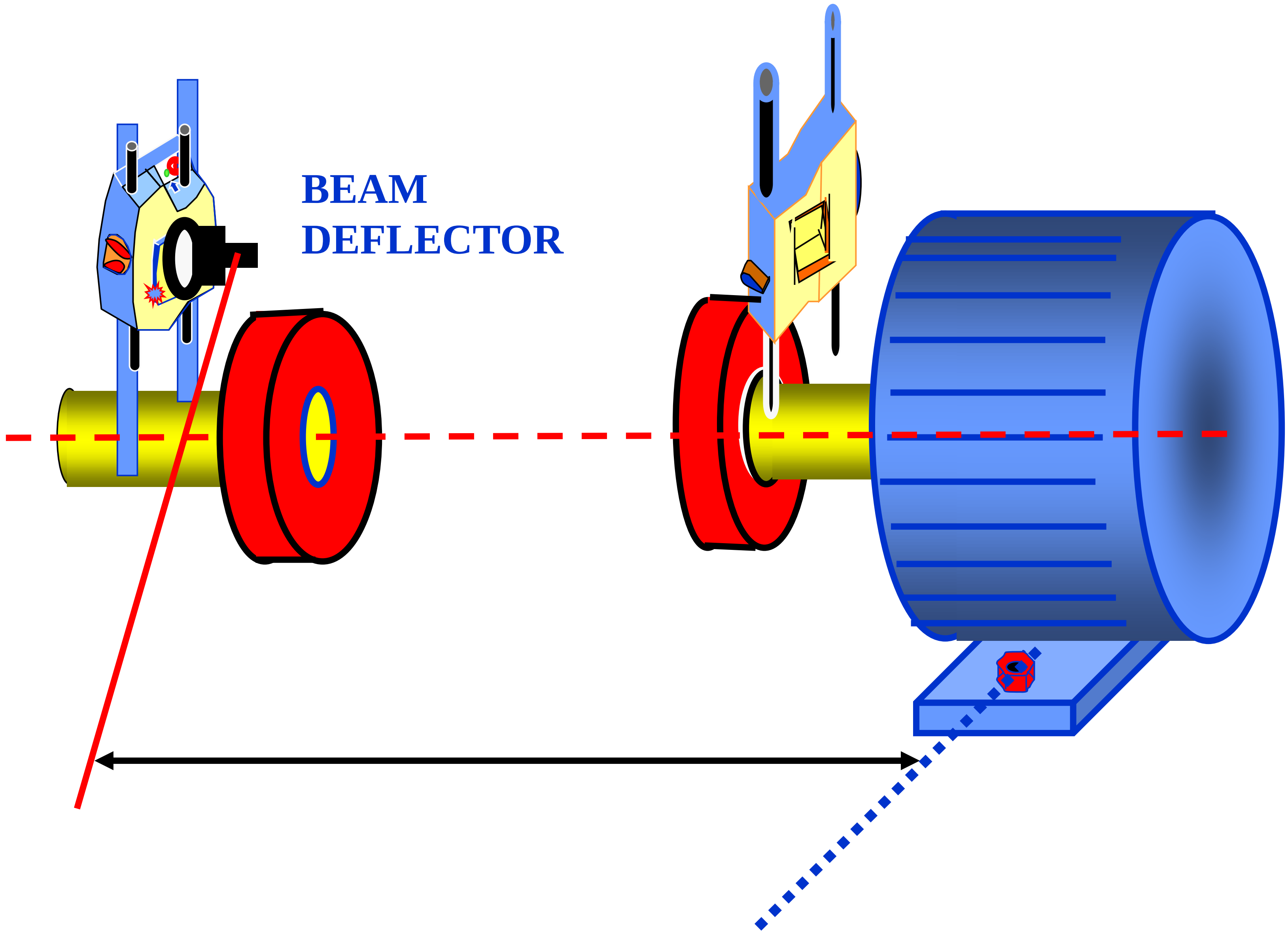
DIM

3- Coupling diameter D

4-Transducer to front foot, right m/c

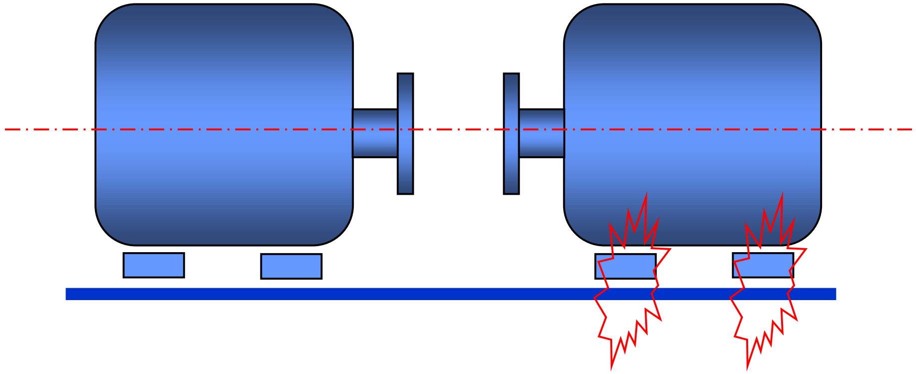


DIM



DIM

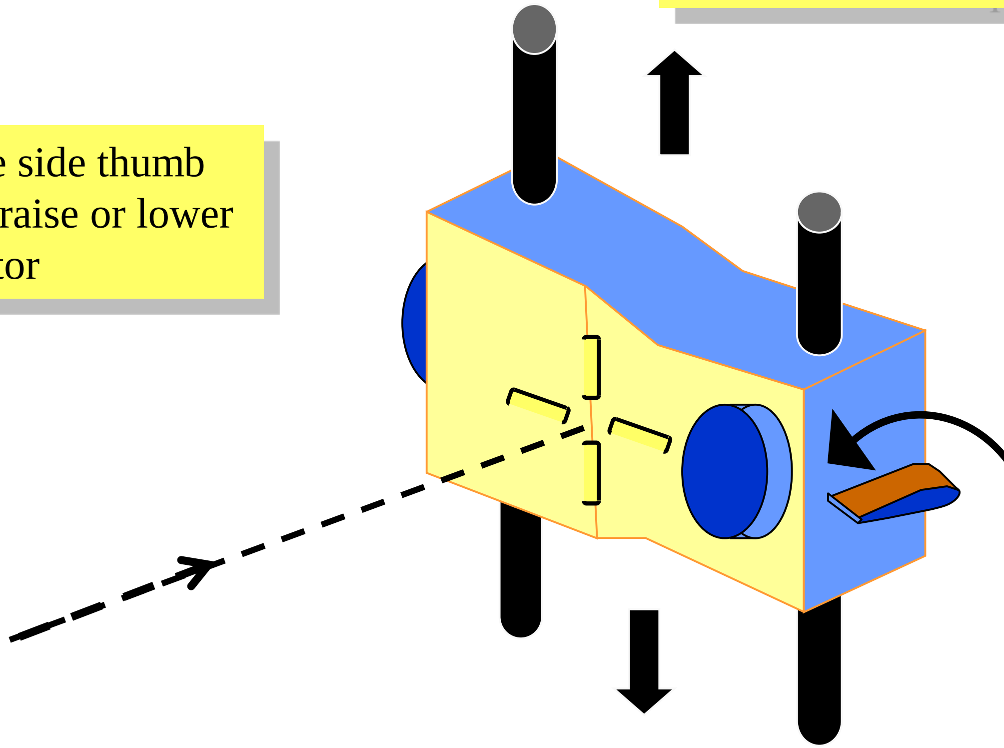
5-Front foot to back foot , right m/c



5-Laser beam adjusting

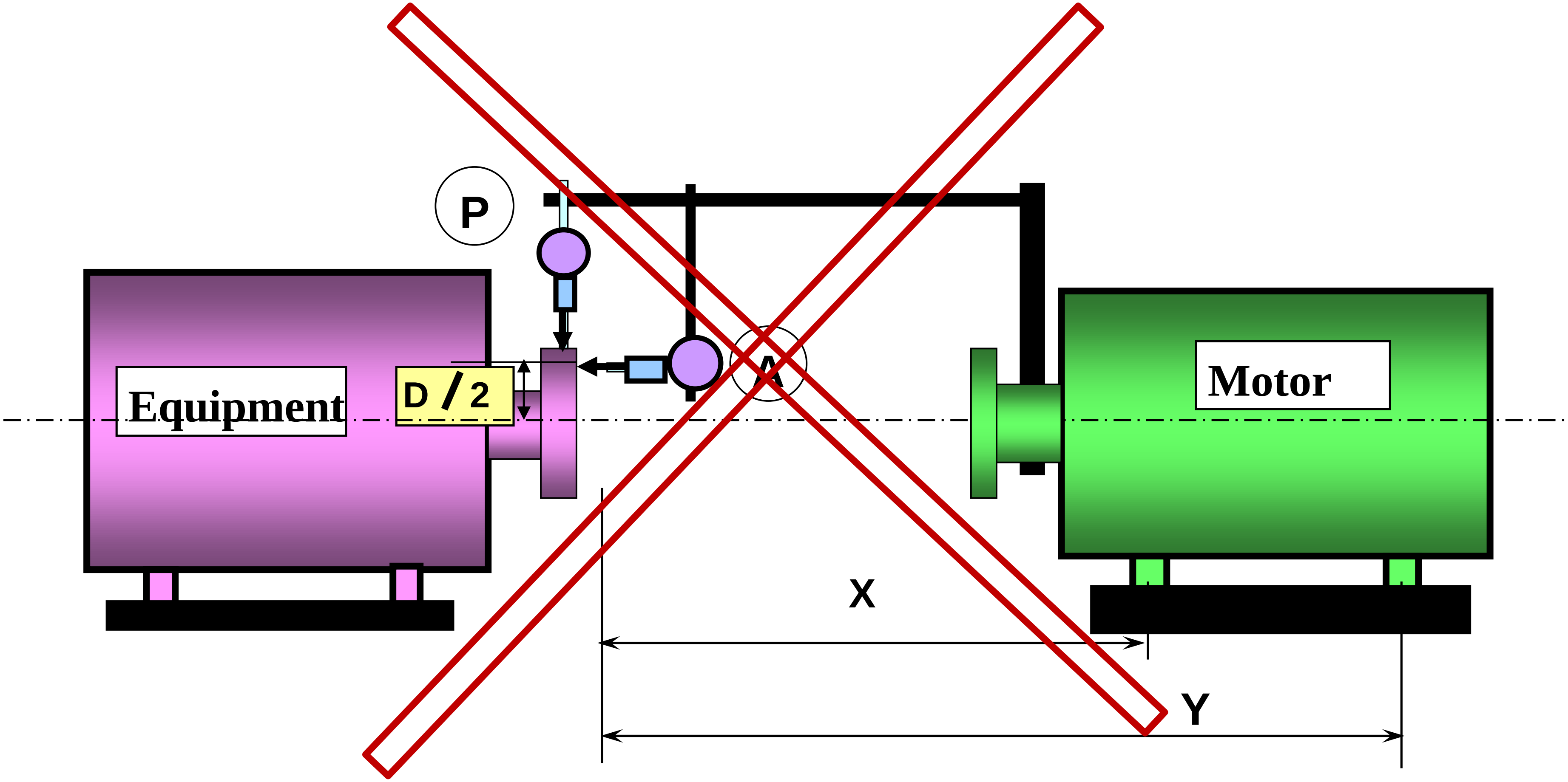
1- PRESS and remove transducer cap.
-The laser beam now is on.
-Leave the reflector cap on for now.
-Beam strikes the cap, it should be visible.
- Hold a sheet of paper to locate the beam

Rotate the side thumb
Wheel to raise or lower
the reflector



This lever to lock
The reflector position

Rim and Face



~~Rim and Face Alignment~~

is prohibited all over the world because of the rotor axial movement affects the dial indicator face reading

Use only

--Reversal Alignment or

--Optical Alignment